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Quality Requirements - The VTT-GEO Geotextile Specification

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ABSTRACT

In autumn 1980 the Finnish Road Administration adopted the VTTGEO geotextile specification for its district organisation's works and annual purchases of non-woven geotextiles. Together with additional requirements for an effective opening size, the VTT-GEO specification was later used for classifying geotextiles in Sweden, too / 6/. The specification was based on experience gained from geotextile applications in road constructions in Scandinavia since the early '70s. Its general principles made use of the first classification of fabrics which was published by the Nordic Road Federation in 1977. The division into application classes according to the shape and size of the coarsest soil particles coming in contact with the geotextile and the the establishing of the corresponding group requirements had been done by the Norwegian Road Research Laboratory (NRRL).

In the VTT-GEO specification the geotextile properties were rated by assigning them points and then evaluated according to the key principle of weighted groups of properties as follows:

mechanical properties	50 - 60%
hydraulical properties	30 - 40%
handling parameters and uniformity	10 - 15%

The quality of delivered products could be checked on site with an additional simple field testing procedure. Adding handling parameters to the specification guaranteed that the rolls delivered were of a size convenient for manual handling on site.

However, owing to the easy selection of geotextiles permitted by the specification road construction consultants did not learn to use more sophisticated design methods when applying geotextiles in structures other than roads. The VTT-GEO specification was misused in a wide range of geotextile applications, for which it was never intended as such.

Progress in European standardization work made it necessary to introduce new and commonly accepted standard procedures for specifying non-woven geotextiles for road applications. Instead of a weighted rating system, limit values had to be assessed for different mechanical and hydraulic properties and also for uniformity parameters. The selection procedure is determined by the coarsest contact material, either supporting the fabric or resting on it. The mechanical requirements for geotextiles depend on the gradation and shape of the material in contact with the fabric, on the installation and compaction methods used and on site /access traffic during and after the construction period. Other important selection criteria for a geotextile to be used for separation and drainage purposes are effective pore size, permeability, elongation and survivability rupture resistance. It has to be able to withstand the stresses caused by construction traffic and compaction of the soil layer coming in contact with it.

For applications, where the mechanical stress is limited, e.g. when protecting road cut slopes against erosion, in pipe trenches etc., the demands on the geotextile can be less strict, depending on the case.

The selection criteria for the minimum performance of non-woven geotextiles in the 5 application classes in road construction are presented in Table 5.1. The criteria are based on the coarsest material coming in contact with the fabric and relevant traffic and subsoil conditions. Drainage and separation functions are listed separately (Table 5.3).

The limit values specifying the minimum performance of non-woven geotextiles for the five application classes in road construction are presented in Table 5.2. These values are based on almost 400 classification tests performed since 1979. As a rule 40 mechanical and 30 other tests were made on each VTT-GEO classified geotextile. Their average values and standard deviations were compared with the test results from the new test procedures for the VTT-GEO specification.

On-site quality control measures are described. Preference should be given to products manufactured according to a quality standard, e.g. ISO 9001 - 9003.

PREFACE

This report on the VTT-GEO geotextile specification is part of a research programme on methods for testing geotextiles,the objective being to produce complementary test data to underpin the new specification for non-woven geotextiles used in road constructions. . The Finnish National Road Administration granted the work on the comparison of different test methods, which also utilized the test data collected during a period of over 12 years, and, in addition, provided information on the experience gained with the use of geotextiles in different applications. The Swedish National Road Administration and the Swedish Geotechnical Institute participated in an exchange of ideas concerning the principles and practical application of the VTT-GEO geotextile specification.

The revision of the VTT-GEO geotextile specification was commissioned by the Geocenter of the Finnish National Road Administration and followed up by Principal Supervisor R. Orama of the Geocenter. Civ.eng. I. Brorsson and civ.eng. L. Strömberg of the Swedish National Road Administration and civ.eng. L. Eriksson of the Swedish Geotechnical Institute gave their full support to the project at its different stages. At the Road, Traffic and Geotechnical Laboratory of the Technical Research Centre of Finland the project was supervised by Senior Research Engineer H. Rathmayer. He was assisted by Research Eng. M. Juvankoski, R. Laaksonen and J. Takala and the Research Assistants R. Seppälä, H. Jukka and V. Räty.

CONTENTS

1 BASIC PRINCIPLES OF THE VTT-GEO SPECIFICATION

1.1 Introduction

In 1980 the Geotechnical Laboratory of the Technical Research Centre of Finland established a new, the "VTT-GEO" specification for non-woven geotextiles to be used in road constructions /1/. This specification was the result of a project involving nine geotextile producers and major geotextile users including the Finnish National Road Administration and several Finnish cities.

Basic information was derived from recovered geotextiles, which had been in service in permanent road constructions for a period of 1.5 - .7 years. The geotextiles of five manufacturers were recovered by the Finnish National Road Administration's district organisations and the City of Vaasa from 22 road sites in different parts of Finland. The results, which are reported in detail in ref. /3/ and /4/, indicated, that the strength requirements of non-woven geotextiles must first and foremost be related to the installation procedure and the techniques used at its different stages.

In autumn 1980 the Finnish Road Administration had adopted the "VTT - GEO" specification for its district organisation's works and annual purchases, and non-woven products were generally marketed according to the new system. Together with additional requirements for an effective opening size, the VTT-GEO specification later served as a basis for classifying geotextiles in Sweden /6/.

The VTT-GEO specification was based on the experience gained from geotextiles used in road constructions in Scandinavia since the early '70s. Its general principles were based on the first classification of fabrics compiled by the Norwegian Road Research Laboratory (NRRL) and published in 1977 by the Nordic Road Federation, which had been elaborated under the responsibility of . The division into application classes according to the shape and size of the coarsest soil particles coming in contact with the geotextile was adopted as such from the NRRL classification (= group requirements). The NRRL classification was based on dry fall cone tests, CBR-penetration tests and some as yet unpublished rules of thumb. A new drop cone test with water support /7/ and a new cone pull-out test /8/ were developed for the VTT-GEO specification. These replaced the dry fall cone test and the CBR-penetration test of the NRRL classification system. The troublesome and time consuming measurement of water permeability was replaced by an air permeability test. Additional measurements of compressed thickness, mass density and grab tensile strength provided the necessary parameters for the assessing functional requirements. Six different test methods were applied.

At least 10 single tests were performed for each test method and test direction. The test data were then averaged and the standard deviation was calculated and deducted from the average value, except in the fall cone test, when the standard deviation was added to the average value of the hole size.

In the VTT-GEO specification the geotextile properties were evaluated according to a rating system and based on the key principle of weighted groups of properties as follows:

mechanical properties	50 - 60%
hydraulic properties	30 - 40%
handling parameters and uniformity	10 - 15%

1.2 Short description of the test procedures and the principles of test evaluation in the VTT-GEO specification

Three groups of properties were covered by the tests. a: mechanical, b: hydraulic and c: handling parameters and uniformity. The test methods and the properties determined are listed in Table 1.1.

Table 1.1. Test methods used for the VTT-GEO specification and their application.

GROUP OF PROPERTIES/ TEST METHOD	PROPERTIES REFLECTED BY TEST PROCEDURE
a: MECHANICAL	
CONE PULL-OUT	tensile and tear resistance, elongation
[NT BUILD 242]	tensile resistance after initial strain
GRAB TEST	tensile resistance,
[ASTM D4632-86,mod.]	uniformity of mechanical properties
CONE DROP TEST	impact resistance
[NT BUILD 243]	
b: HYDRAULIC	
AIR PERMEABILITY,	permeability
THICKNESS &	
MASS DENSITY	porosity
CONE DROP TEST	partially permeability (water-supported test)
[NT BUILD 243]	
c: HANDLING PARAMETERS AND UNIFORMITY	
ROLL SIZE &	
ROLL MASS	handling on site
MASS VARIATION	uniformity

Most of the tests were performed by the Technical Research Centre of Finland subject to the following conditions. The geotextile samples had to be taken by an independent body from the stock (of representative quantity) held by the importer .Test certificates had to be valid for one calendar year.

For quality checking on site a simplified procedure consisting of plunger pull-out tests, fall cone tests, and measurements of thickness and mass density was developed. Only averages based on limit values of points given for each application class. were used for the acceptance criteria.

MASS VARIATION reflects the homogeneity of the product. Owing to the production processes involved, some variation in mass has to be accepted. For the user, the greater the mass variation, the more disadvantageous the inhomogeneity becomes.

The 25 mm GRAB TENSILE TEST indicates the variation in strength properties depending on the direction of testing. For the most civil engineering applications only the strength values in the direction in which the material is weakest will be of advantage to the user. The strength ratio obtained in the grab test is used to reduce the out of plain strength values from the cone pull-out test.

THE CONE PULL-OUT force describes the ability of the geotextile structure to conform to the unevenness of the underground without rupturing. The tensile resistance available after the initial strain, which is due to the installation process, is derived from the pull-out force at an initial plunger travel of 20 mm and at its maximum travel. The elongation criterion is derived from the plunger travel at maximum pull-out force, and the additional friction criterion from the vertical component of the clamping force developing during the final stage of the test.

The punching and permeability criterion is derived from the hole size in the CONE DROP TEST WITH WATER SUPPORT. This dynamic impact test mainly measures the resistance of the geotextile in separation function, but to some extent also its permeability. A geotextile of poor permeability is less able than one of good permeability to withstand the energy input of the fall cone and the resulting shock wave of the displaced water.

THE AIR PERMEABILITY value, when set in relation to the porosity of the geotextile indicates the performance of the product in filtration function.

HANDLING PARAMETERS, e.g. roll size, roll mass and width, take into account practical aspects of the installation procedure. These parameters also affect safety regulations for workmen and the final installation costs.

Durability properties, some of which might be very important in several applications were omitted. Information and, if necessary, a warranty on UV stability, chemical and biological resistance should be given to the user by the manufacturer.

2 EXPERIENCE GAINED FROM THE VTT-GEO SPECIFICATION

+ Based on long term experience a wide range of different products could be specified for the use in road construction works.

+ The Finnish National Road Administration and its district organisations, the construction departments of big towns and other major users obtained a simple tool enabling them to purchase the most suitable geotextile out of the range of products available for a particular application.

+ When combined with an annual tender for some millions of square meters of material, the major users could negotiate the most advantageous purchase conditions.

+ A simple field testing procedure enabled the quality of products delivered to be checked on site.

+ Adding handling parameters to the specification guaranteed the delivery of rolls of a size convenient for manual handling on site.

- Owing to the easy selection of geotextiles, the consultants responsible for the design of road structures did not learn to use more sophisticated design methods when applying geotextiles in structures other than roads.

- The VTT-GEO specification was misused in a wide range of geotextile applications for which it was never intended in the first place.

3 SHORTCOMINGS OF THE TESTING PROCEDURES USED IN THE VTT-GEO SPECIFICATION

The uniformity coefficient A, which describes the ratio of tensile strength in machine direction to that in transversal direction, is determined with the GRAB tensile test (ASTM D 4632-86, modified) /9/.

Some criticism has been expressed regarding the applicability of a grab test to describe the tensile strength in a certain direction; reasons for this scepticism may be due to the geometrical lay-out of the grab test, to the sample size versus the clamp configuration. On the other hand practical experience has shown that the grab test may well simulate the stresses induced to the geotextile during the installation procedure in the field.

The concentration of the clamping force in certain parts of the geotextile specimen is a potential risk of sample damage in the clamping area and may result in misinterpretation of the grab test data.

The testing methods of the VTT-GEO specification were used only exceptionally for production control at the plant. The application of a rating system required, in principle, that the whole range of tests had to be performed before the VTT-GEO application class could be established. The inclusion of quality control testing in the VTT-GEO procedure had to be compensated by way of a simplified field control system.

The simplified field testing procedure requires two special instruments (one for the fall cone test and another for the cone pull-out test), a micrometer and an accurate balance. The air permeability values needed for the rating are taken from an updated table. With the exception of the district organisations of the Finnish National Road Administration, quality assurance on site was done by visual inspection only.

4 NEW TESTING PROCEDURES - COMPARISON OF RESULTS

4.1 WIDE-WIDTH TENSILE TEST - tensile strength and elongation

A selection of samples already tested for the VTT-GEO classification procedure were tested as required by the recently issued standard ISO 10319 - Geotextiles - Wide-Width tensile test /10/.

Testing procedure

Tensile strength is tested on 200-mm-wide samples with a measuring length of 100mm and a deformation rate of 15 -20%/min. The tensile tests are carried out on 10 samples in longitudinal and transversal directions. Samples are taken as required by the prEN 963 standard at least 0.3m from the fabric edge. Tensile strength and the corresponding elongation values are determined at break, at an elongation of 20% and, if required, at points corresponding to other limit criteria in each single test. The average and the standard deviation are calculated for each set of 10 test values.

Test conditions

The size of the geotextile samples was prepared to 200mm x 200mm. The faces of the hydraulically operated compressive jaws were machined to a smooth sinusoidal shape to prevent slippage of the geotextiles.

The sample was submitted to extension with a preload corresponding to 1% of the maximum expected load.The strain rate was 20 mm/min (20% /min). The results were collected directly into data files large enough to contain all the data.

Tested samples

The retested samples can be identified from the information given in Table 4.1.

Results

The wide-width tensile test results of the products listed in Table 4.1 are summarised in Tables 4.2 - 4.7 (appended), and the load vs. strain curves for the machine and transversal directions are given in Figures 4.1 - 4.17 (appended) for each product type, grouped according to the VTT-GEO application classes.

The tables present the maximum tensile strength and the corresponding elongation for each single test, and also the average values and standard deviations for a set of 8 - 10 tests. The uniformity coefficients A showing the ratio of the strength in the transversal direction to that in machine direction are also listed.

The correlations between the maximum tensile strength values of the Grab tensile test (ASTM 4632-86, modified) and the new Wide-Width tensile test (ISO 10 319) are given in Figures 4.18 - 4.19 (appended), and between the maximum pull-out force in the Pull-Out test (NT BUILD 242) and the maximum tensile strength in the Wide-Width tensile test in the Figures 4.20 - 4.21 (appended). Each point in the graphs represents the average of ten test results.

4.2 DYNAMIC IMPACT TEST - cone drop test

The cone drop test is performed using the standard procedure prEN 918/11. In the test the geotextile specimen is clamped across a CBR cylinder with an inner diameter of of 150mm. A 45° cone, 50mm in diameter and 1000g in mass, is dropped onto the specimen from a height of 0.5 m. The resulting hole is measured with a measuring cone weighing 600g. Ten tests are performed and the average is reported.

Th hole sizes determined with cone drop tests according to NT BUILD 243 (geotextile supported by water) and according to prEN 918 (dry test) are compared in Fig. 4.22. The significant difference in hole sizes between the dry and wet tests indicates the safety margin of mechanically bonded geotextiles used for separation purposes in a moist environment.

4.3 WATER PERMEABILITY NORMAL TO THE PLANE

A standard test method for water permeability normal to the plane of a geotextile is being developed by WG-4 of CEN TC 189. It is unlikely that a draft prEN will be issued before 1994/95. For the time being testing procedures based on either the falling head or constant head technique will be accepted.

Water permeability tests with the constant head technique were conducted for the geotextile samples listed in Table 4.1. The water head difference applied in the tests was 0.3..0.35m. The results are given in Table 4.8.

The air permeability and water permeability values for the same geotextile types are compared in Fig. 4.23. The test results of both properties show an variation of an order of magnitude.

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4.4 EFFECTIVE OPENING SIZE - O_{90}

The effective opening size, O_{90}, of a geotextile is determined using the wet sieving test originally developed at the Franzius Institute Hannover (FIH - Technical University Hannover). This method will be issued as a prEN standard in 1994/95, and the necessary preparations are currently being undertaken by WG-4 of CEN TC 189.

Since 1989, the Swedish National Road Administration has required limit values as in BYA Komplement 4/89 /6/ for the effective opening size, O_{90}, of geotextiles used for separation purposes in road constructions.

The geotextiles listed in Table 4.1 were tested using the FIH method, and the results are listed in Table 4.8.

Table 4.1 Brand names and types of geotextile retested for the new geotextile specification.

Product type	Mass, W_{test} g/m²	Lab.no.	Originally tested for VTT/GEO specification year	use class
1. Trevira Spunbond				
110 g/m²	120,0	6500	1990	2
150 g/m²	166,1	6501	- " -	3
300 g/m²	361,5	6502	- " -	4
2. Polyfelt				
TS-22T	118,2	6516	1990	2
TS-521	206,6	6517	- " -	3
TS-750	385,0	6518	- " -	4
3. Fibertex				
F2-B	152,5	3151	1984	2
F32-M	192,9	3162	- " -	3
F4-M	350,9	3152	- " -	4
4. Terram				
1000	131,5	3154	1984	2
1500	186,6	3155	- " -	3
3000	277,3	3156	- " -	3
5. Typar				
136 g/m²	143,3	3164	1984	2
230 g/m²	234,9	3165	- " -	3
6. Bidim				
B-1	111,8	6139	1989	2
B-3	172,1	5408	1987	3
B-7	349,9	6143	1989	4

TABLE 4.8. Water permeability and permittivity of geotextiles normal to the plane (constant head tests) and Equivalent opening size O_{90}.

PRODUCT TYPE	Lab.no	W_{test} g/m²	Thickness at 2 kPa [t] mm	Permeability [k] m/s*10^{-3}	Permittivity [Ψ] 1/s	Effective Opening Size [O_{90}] mm
1. Trevira Spunbond						
110 g/m²	6500	120,0	1,18	1,73	1,47	0,123
150 g/m²	6501	166,1	1,43	1,94	1,35	0,087
300 g/m²	6502	361,5	3,24	3,39	1,05	0,117
2. Polyfelt						
TS-22T	6516	118,2	1,16	1,77	1,53	0,138
TS-521	6517	206,6	2,0	2,95	1,48	0,136
TS-750	6518	385,0	2,95	4,30	1,46	0,133
3. Fibertex						
F2-B	3151	152,5	1,09	1,63	1,49	
F32-M	3162	192,9	2,0	2,41	1,20	
F4-M	3152	350,9	2,93	4,60	1,57	
4. Terram						
1000	3154	131,5	0,88	1,05	1,19	0,131
1500	3155	186,6	0,93	0,79	0,85	0,131
3000	3156	277,3	1,32	0,87	0,66	0,118
5. Typar						
136 g/m²	3164	143,3	0,47	0,12	0,27	
230 g/m²	3165	234,9	0,58	0,05	0,08	
6. Bidim						
B-1	6139	112,7	1,03	1,45	1,40	0,139
B-3	5408	172,1	1,82	2,60	1,43	0,136
B-7	6143	349,9	2,74	3,12	1,14	0,097

5 REVISED VTT-GEO SPECIFICATION

5.1 General lay out

The main selection criteria for a geotextile used for separation purposes are the gradation and shape of the materials coming in contact with the fabric. The coarsest contact materials either supporting the fabric or resting on it determines the selection procedure.

It is assumed that the layer above the fabric is compacted and that there is access traffic at the construction site. In applications, in which the mechanical influence is limited, e.g. in the protection of road-cut slopes from erosion and in pipe trenches, the demands on the geotextiles need not to be so strict and can be determined case by case.

5.1.1 Selection criteria for a minimum performance geotextile

The mechanical requirements for geotextiles depend on
- the material which is installed against the fabric
- the installation and compaction methods used
- site-access traffic during the construction period.

The revised VTT-GEO geotextile specification, which is applicable to non-woven geotextiles in road constructions, defines selection criteria for each application-class as set out in Table 5.1 for a minimum performance geotextile. The acceptance criteria for geotextiles in applications corresponding to the application-classes are presented in Table 5.2, in general in the form of limit values imposed on average material properties, as explained in detail in Chapters 5.2..5.9.

The first four application classes follow, in principle, the Norwegian proposal presented in NVF-78, Utsk. 31-5 /5/ and also published in the proceedings of the "1st Int. Geotextiles Conference" , 1. IGC, PARIS 1977 /12/. A 5th application class - FOR SOFT SOIL / ROCKFILL - has also been introduced. This additional application class permits the setting of an upper limit for application class 4. As a special requirement, the hole size in the dynamic impact test (= drop cone test, prEN 918) is to be close to zero (on average $\phi < 5$ mm).

Table 5.3 serves as an aid to the selection of geotextile's in road constructions. The specifications of the required application-classes depend on the primary geotextile function, on type of subsoil, the traffic load and on the construction materials used.

Table 5.1 Criteria for the minimum performance of geotextiles on the basis of the coarsest material coming in contact with the geotextile, the type of application and the subsoil.

	Permanent and access roads	
AREA OF APPLICATION	**compressible subsoil s_u > 25 kPa**	**soft to very soft subsoil s_u < 25 kPa**
1	In drainage trenches and for erosion protection etc., against natural backfill material, mainly unbroken **1)**	NOT APPLICABLE !
2	Against gravel < **60 mm** and natural material, mainly unbroken 1)	In drainage trenches and for erosion protection, etc., against natural material, mainly unbroken
3	Against broken stone or sorted, blasted rock < **200 mm** 1)	Against gravel < **60 mm** and natural material, mainly unbroken
4	Against broken stone or sorted, blasted rock > **200 mm** 1)	Against broken stone or sorted, blasted rock < **200 mm**
5	In severe loading, environmental or installation conditions 1)	Against broken stone or unsorted blasted rock > **200 mm**

1) In the event of heavy traffic moving on access roads, the geotextile should be selected from the column "soft to very soft subsoil".

Table 5.2 THE NEW VTT-GEO GEOTEXTILE SPECIFICATION

	GTX-appl. class 1	GTX-appl. class 2	GTX-appl. class 3	GTX- appl. class 4	GTX-appl. class 5
MASS VARIATION	$W_{nom} - 1.5 * s_w < W_{test} < W_{nom} + 1.5 * s_w$			$W_{nom} - s_w < W_{test} < W_{nom} + s_w$	
permitted $s_{w,max}$ = for sample size 200*200 mm	12.5%	12.5%	10%	10%	10%
permitted $s_{w,max}$ = for sample size 0.5 * 0.5 m (for field testing)	8.5%	8.5%	6.5%	6.5%	6.5%
UNIFORMITY A =	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
TENSILE STRENGTH [kN/m]	> 5	> 7	> 11	> 19	> 30
ELONGATION [%]	> 30	> 45	> 50	> 50	> 50
SURVIVABILITY RUPTURE RESISTANCE after 20% initial strain	> 20% of P_{max} [kN/m]	> 30%	> 40%	> 50%	> 50%
DROP CONE hole size ϕ [mm]	< 45	< 40	< 26	< 17	< 5
EFFECTIVE OPENING SIZE O_{90} [mm]	0,2	< 0,15	< 0,15	< 0,15	< 0,15
WATER PERMEABILITY [m/s * 10^{-4}]	> 1	> 1	> 1	> 1	> 1

Table 5.3 Selection of minimum performance geotextile in separation and/or drainage function for road applications.

a) PRIMARY GEOTEXTILE FUNCTION: SEPARATION **b) PRIMARY GEOTEXTILE FUNCTION: DRAINAGE (values given in brackets)**

SUBSOIL	GRANULAR MATERIAL	TRAFFIC	MINIMUM PERFORMANCE GEOTEXTILE at maximum stone size #, mm # >200	# = 60-200	# <60
VERY SOFT	CRUSHED/ANGULAR	HEAVY	5	4	4
c_u < 25 kPa		MEDIUM	4 (4)	4 (4)	3 (3)
		LIGHT	(3)	(3)	(2)
(clay & silt, silty clay & silty till)	ROUND/NATURAL	HEAVY	4	3	3
		MEDIUM	3 (3)	3 (3)	2 (2)
		LIGHT	(2)	(2)	(2)
SOFT	CRUSHED/ANGULAR	HEAVY	4	3	3
c_u > 25 kPa		MEDIUM	4 (4)	3 (3)	2 (2)
		LIGHT	(3)	(3)	(2)
	ROUND[1)]	HEAVY	4	3	2
		MEDIUM	3 (3)	3 (3)	2 (2)
		LIGHT	(2)	(2)	(1)

[1)] including crushed gravel # < 60 mm.

Heavy traffic: > 1500 veh./d
Medium traffic: 500 - 1500 veh./d
Light traffic: < 500 veh./d

5.2 Mass variation and uniformity of material structure

5.2.1 Limit values for laboratory control tests

The permitted mass variation is limited to

$s_{w,max}$ = 12.5% (for geotextile application classes 1 and 2)

$s_{w,max}$ = 10% (for geotextile application classes 3 - 5)

The value of the permitted mass variation, $s_{w,max}$, is determined from 10 samples 200 x 200 mm in size and is integrated with the average mass of the test lot W_{test}. Sampling and preparation of test specimens are in accordance with prEN 963.

When geotextile properties are evaluated on the basis of laboratory tests the deviation must be less than 1.5 * std. dev. (application classes 1 - 3) and 1,0 * std. dev. (application classes 4 and 5) in relation to the nominal mass.

$W_{nom} - 1.5 * s_w < W_{test} < W_{nom} + 1.5 * s_w$ (appl.classes 1..3)

$W_{nom} - s_w < W_{test} < W_{nom} + s_w$ (appl. classes 4 and 5)

5.2.2 Limit values applied to field control tests

A sample 500 * 500 mm in size should be used for the control of geotextile mass in field tests. The permitted mass variation, $s_{w,max}$, and the average mass of the test lot W_{test} are determined from a minimum of five samples. The corresponding limits for this bigger sample size are

$s_{w,max}$ = 8.5% (for geotextile application classes 1 and 2)

$s_{w,max}$ = 6.5% (for geotextile application classes 3 - 5)

5.2.3 Experimental background

The limits given here are based on almost 400 classification test series performed since 1979. As a rule the mass and mass variations were determined from 10 samples 200 x 200 mm in size and from another five samples 1.0 x 1.0 m in size. New information on the effect of sample size on the variation coefficient was applied, especially in the determination of field limit values.

5.3 Uniformity = A - value

5.3.1 Basic principles

The criterion estimates the ratio of $\bar{P}_{max,strong}$ to $\bar{P}_{max,weak}$

The ratio is determined using the unidirectional average values of 10 wide-width tensile tests (ISO 10 319) performed in machine direction and 10 tests performed in transversal direction.

The permitted uniformity value A_{alw} must not exceed 1.5.

$A_{alw} = \bar{P}_{max,strong} / \bar{P}_{max,weak} < 1.5.$

5.3.2 Possible acceptance of products with uniformity values A > 1.5

In the three criteria listed below, which estimate the average values of the tests performed in machine and in transversal directions,

a) maximum tensile strength $\bar{P}_{max}$,

b) elongation $\bar{\varepsilon}_{max}$ at $\bar{P}_{max}$ and

c) survivability rupture resistance $\bar{P}_{srr}$ $\qquad$ $(P_{srr} = P_{max} - P_{=20})$

instead of using P_{max} and the corresponding ε_{max} for the stronger geotextile direction the average values of the two directions are calculated from corrected limit values, which are determined for each single test separately, as follows

$P_{lim} = 1.5 * \bar{P}_{max,\ min.dir}$

and correspondingly ε_{lim}

NOTE:

WITH THE APPLICATIONS IN QUESTION, THERE IS NO GUARANTEE THAT THE GEOTEXTILE CHOSEN HAS BEEN INSTALLED PERPENDICULAR TO THE ROAD AXIS.

5.3.3 Experimental background

The limits given in Table 5.2 are based on almost 400 classification test series performed since 1979. In general 10 grab tensile tests (ASTM 4632-86, mod.) in both machine and transversal directions were made to determine the uniformity coefficient A. The calculation was based on the directional average values of maximum tensile strength reduced by a single standard deviation.

A values from grab tests and their scatter are given in Fig. 5.1 for a set of geotextiles classified according to the VTT GEO scheme. For all three classes the average of the uniformity coefficient was around 1.13 with a standard deviation of 0.1..0.13. Uniformity does not appear to improve with time.

This statistical evaluation cannot be directly applied to the wide-width tensile test results for the following reasons. Although the maximum tensile strength values of the grab tensile tests (ASTM 4632-86, modified) correlate well, on average, with the strength values from the wide-width tensile test (ISO 10 319), - see Fig.s 4.18 - 4.19, the same cannot be said for the values of the strength ratio (= uniformity coefficient).

The strength values determined in the grab tensile test do not depend so clearly on the direction of testing as they do in the wide-width tensile tests. Especially the heat-bonded geotextiles benefit from the clamping geometry used in the grab tensile test. The fabric area resisting the tensile stresses obviously extends laterally outside the straight rectangular between the clamps. In practice, this means that a greater number of intact fibres contributes to the test results.

For these reasons and based on the clear results of the wide-width tensile tests, the limit for the uniformity coefficient A was set to $A_{alw} < 1.5$ for all application classes.

5.4 Tensile strength

5.4.1 Basic principles

The limit values given in Table 5.2 for the different application classes are expressed as

the average values of $\overline{P}_{max}$

to be determined with 10 wide-width tensile tests (ISO 10319) in the machine (=length) direction and with 10 tests performed in the transversal direction. To ensure that the average values are sufficiently reliable it is essential that 10 tests should be performed in each direction.

For geotextiles with a uniformity coefficient A > 1.5 the values of the maximum tensile strength, $\overline{P}_{max}$, for the stronger direction are replaced by corrected limit values, which are determined for each test separately, as

$$P_{lim} = 1.5 * \overline{P}_{max,\ min.dir}$$

5.4.2 Experimental background

The limits given here are based on almost 400 classification tests performed since 1979. In general 10 cone pull-out tests (NT BUILD 242) were made to determine the average values of maximum pull-out strength. Correlations of maximum pull-out strength and maximum tensile strength in the wide-width tensile test (ISO 10 319) are given for machine and transversal directions in Fig. 4.20. The highest correlation between cone pull-out maximum strength and wide-width tensile strength seems to exist in the weaker direction. A comparison with the average tensile strength values is presented in Fig. 4.21.

Average values of cone pull-out strength values are given together with their standard deviation in Fig. 5.2 for VTT-GEO classified geotextiles. with the aid of the correlations given in Fig. 4.21, these statistically determined $\overline{P}_{max}$ values of the cone pull-out test can be transformed to the limit values of average $\overline{P}_{max}$ of the wide-width tensile test.

5.5 Elongation

5.5.1 Basic principles

The limit values given in Table 5.2 for the different application classes are expressed as the average (10 tests in each direction) deformation $\bar{\varepsilon}_{max}$ measured in the wide-width tensile test (ISO 10 319)

$$\bar{\varepsilon}_{max} = (\bar{\varepsilon}_{max,length} + \bar{\varepsilon}_{max,transversal}) \times 0.5$$

For geotextiles with a uniformity coefficient A > 1.5 the elongation values, $\bar{\varepsilon}_{max}$, at maximum tensile strength $\overline{P}_{max}$ for the stronger direction are replaced by corrected limit values ε_{lim}, which are elongation values determined for each single test separately corresponding to

$P_{lim} = 1.5 \cdot \overline{P}_{max,\ min.dir}$ (see also Fig. 5.7).

5.5.2 Experimental background

The given limit values are based on almost 400 classification tests performed since 1979. In general 10 cone pull-out tests (NT BUILD 242) were made to determine the average values of plunger travel at maximum pull-out strength. These values are presented together with their average values and standard deviation in Fig. 5.2 for VTT-GEO classified geotextiles. The graphs show a certain tendency towards lower elongation values starting in the mid-'80s. Average elongation values for the wide-width tensile tests (bi-directional average) exceed the corresponding cone pull-out values by 20 - 30%.

Deformation values derived from the cone pull-out test reflect the out of plane behaviour of a point-loaded geotextile. Uniaxial testing can scarcely provide information on out-of-plane behaviour. The limit values considered as acceptance criteria for geotextiles in application classes 1 - 5 represent a minimum of the deformability required to cope with both uneven subsoil conditions and the roughness of the aggregate compacted onto the geotextile. High lateral deformation values have been observed in geotextiles, especially under tyre loads in unpaved traffic areas.

5.6 Survivability rupture resistance after 20% initial strain

5.6.1 Basic principles

The criterion estimates the capacity of a geotextile for differential load take-up in the deformation range between ε = 20% and ε at P_{max} (= ε_{max}).

The limit values given in Table 5.2 are determined as averages of the differential values (P_{max} - $P_{\varepsilon 20}$) from 10 wide-width tensile tests (ISO 10 319) in the machine direction and 10 wide-width tensile tests in the transversal direction.

$\bar{P}_{srr} = P_{max} - P_{\varepsilon 20}$

For geotextiles with a uniformity coefficient A > 1.5 the maximum tensile strength values, P_{max}, for the stronger direction are replaced by corrected limit values, which, determined separately for each single test are

$P_{lim} = 1.5 * \bar{P}_{max,\ min.dir}$

The corrected differential values for the stronger direction are thus

$\bar{P}_{max,\ red} = \bar{P}_{lim}$

$\bar{P}_{srr} = P_{lim} - P_{\varepsilon 20}$ (see also Fig. 5.7).

5.6.2 Experimental background

The given limit values are based on almost 400 classification tests performed since 1979. In general, 10 cone pull-out tests (NT BUILD 242) were made to determine the average values of pull-out strength at a plunger travel of 20 mm and at maximum strength. A typical correlation of these values to strength values of the wide-width tensile test (ISO 10 319) at an elongation of 20% is given for the weaker direction in Fig. 5.4.

5.7 Water permeability

5.7.1 Basic principles

The geotextile (gtx) has to meet the conformity criterion

$k_{gtx} > 100 * k_{soil}$ in all applications.

The lower limit value of water permeability k_{gtx} is at 10^{-4} m/s to allow a sufficient water flow perpendicular to the plane of the geotextile.

5.7.2 Experimental background

The given limit values are based on almost 400 air permeability tests performed for classification purposes since 1979. In general 10 specimens were tested, and the air permeability values were determined at five points of the samples according to the standard procedure of SFS 4782 (= DIN 53 887).The results of tests conducted for VTT-GEO classified geotextiles since 1981, with the average values of air permeability and their standard deviations, are compiled in Fig. 5.5.

Water permeability (and permittivity) values were determined for the geotextiles listed in Table 4.1 using a sample, = 150 mm in diameter, and a constant head permeameter. The results are listed in Table 4.8. The values for water and air permeability are plotted in Fig. 4.23.

5.8 Effective opening size - O_{90}

5.8.1 Basic principles

A geotextile will function as an effective separator between soil layers of different structures only if certain filtering requirements are met. The ability of the geotextile to retain fines mainly depends on the ratio of its effective opening size to the gradation of the soil(s) coming in contact with the geotextile and, to some extent, on the reduced thickness of the compressed geotextile. The thickness reflects the pore volume available for the formation of a stable filter structure.

The effective opening size is determined by the FIH (=Franzius Institut für Wasserbau, Hannover) wet sieving method /18/. The effective opening size O_{90} is defined as the particle size of the soil fraction of which 90% (of dry mass) is retained at the surface of or within the structure of the geotextile. The remaining 10% of finer particles is washed through the geotextile structure during the wet sieving process.

The effective opening size O_{90} should be $O_{90} \leq 0.2$ mm for application class 1, and $O_{90} \leq 0.15$ mm for application classes 2 - 5.

For difficult soils, unstable in respect of suffosion, the additional requirement of $O_{90} \leq d_{85}$ should be met (O_{90} denotes the effective opening size of the filter and d_{85} a characteristic soil grain size).

5.8.2 Experimental background

The given limit values are identical to those set in BYA Komplement 86/4 /6/ for geotextiles to be used for separation purposes in road constructions. The values listed in Table 4.8 were determined with the aforementioned FIH wet sieving tests. The tests were performed with commercial quartz fractions.

5.9 Penetration resistance

5.9.1 Basic principles

In all prospective areas of application the geotextile must have a certain resistance against dynamic impact. This is defined with the dynamic penetration test (= falling weight test, = cone drop test) as the average hole diameter ϕ in mm.

The parameter thus derived correlates with the effect of damage during installation, in relation to the deterioration in quality due to handling and installation on site.

The hole diameter is determined with 10 drop cone tests conducted according to the prEN 918 standard procedure. The specification value of the hole diameter is defined as the average value of 10 tests. Limit values for the hole diameter , in mm, are given in Table 5.2. The limit values correspond to those presented by Alfheim & Sørlie in 1977 /12/, taking into account the usual quality variation in non-woven textile products. For geotextile-application class 5, the diameters of all the holes must be less than 5 mm. For application class 1 the values should be < 50 mm, that is, the falling cone must not totally penetrate the geotextile in any test.

5.9.2 Experimental background

The given limit values are based on almost 400 classification tests performed since 1979. In general, the average values of 10 fall cone tests (NT BUILD 243, water-supported geotextile) together with their standard deviation were used as classification values. The results of test conducted for VTT-GEO classified products since 1981, with the average values of hole sizes, are given in Fig. 5.6.

A series of dynamic impact tests was performed on samples of the geotextiles listed in Table 4.8 using a falling cone according to prEN 918 standard. The results together with the hole sizes from water supported tests are shown in Fig. 4.22.

The test results clearly demonstrate the difference in impact resistance between different types of geotextiles. Needle-punched geotextiles have notably better impact resistance in a wet environment than heat-bonded products. Almost all applications in northern latitudes involve moist soil and / or environment. Selecting geotextiles on the basis of the results of dry tests provides better protection against impact forces, especially for mechanically bonded products.

6 IDENTIFICATION

6.1 Documents

The supplier of a geotextile must provide a

• certificate from an independent and /or official testing institute, showing acceptable test results obtained with the above testing procedures on representative samples - preferably taken from a domestic stock of representative size -, together with a

• certificate indicating that production is controlled and supervised by an official testing body, e.g. according to ISO 9001 - 9003.

The test result certificates must not be older than one year.

6.2 Marking according to ISO 10 320:1991 & pr EN 30 320:1993

• Each unit of geotextiles and similar products must be provided with a label giving the following information in "a Scandinavian" language, Finnish or English language.

a. Producer
b. Place & country of origin
c. Product name
d. Product type
e. Identification of the unit (e.g. production number of the roll)
f. Nominal gross weight per unit expressed in kg
g. Unit dimensions of the geotextile (not of the packaging)
   - Rolled goods: length * width (both in m)
   - other goods: number of units * length * width (both in m)
h. Nominal area mass (g/m^2) according to ISO 9864
i. Polymer types of each component
j. Product description using terms defined in the terminology /15/, /14/ (per unit, may also be in English)
k. CE mark if originating in the EEA

The product name and type must also be marked on the product, e.g. alongside the edge. The marking must be durable and legible for ease of identification at installation.

The marking must be repeated at regular intervals, < 5 m. If the product is further worked up (e.g. cut), thus rendering the original marking illegible, every unit must be provided with a separate identification, which is the responsibility of the party doing the work up (cuts, etc.).

7 INSTALLATION

A geotextile serving as separation layer should be installed lengthwise or transversal to the direction of filling. It should be joined by overlapping, welding, sewing or other suitable means of seaming.

Information on an acceptable joining method is given by the supplier. Under a filling or a subbase, any overlapping join should be at least 0.5 m wide. When the geotextile is installed perpendicular to the direction of filling and joined by overlapping, the join should be made as when tiling a roof, i.e. with panel two under panel one at the joint. Where considerable settlement or deformation is to be expected, the overlap should be increased and the geotextile installed transversal to the direction of filling.

On layers of frost susceptible sediments or soils (= difficult in terms of filtering), the geotextile should be joined by sewing or welding.

A geotextile serving as a separation layer should be well joined on slopes or in drainage systems. It should also be well joined when installed against wells and similar ducts.

The separation layer should have a sufficient inclination if open graded material, such as broken rock is placed upon it.

Geotextiles should be protected against sunlight and be stored under cover; during storage and installation they should not be exposed to sunlight for longer than one week.

Geotextiles should be protected before vehicles are allowed to drive over them. On a stable foundation, the thickness of the protection layer should be at least twice the largest grain size in the protection layer, and not less than 0.3 m.

The thickness of the protective layer should be increased on soft soil foundations.

In addition, the protective layer must be thick enough to ensure that the foundation is not deformed during installation or under normal traffic conditions.

NOTE: The given limit values for layer thickness are valid only for a restricted period of construction. To avoid abrasion induced by traffic a minimum thickness of 0.5 m should generally be required.

Before endtipping is carried out, geotextiles should be covered with a protective layer. The thickness of the protective layer should be twice the largest grain size of the material to be end tipped. A protective cover installed by dozing out can consist of normal fill material, with the largest grain-size being half the thickness of the layer.

If damaged, a geotextile should be protected or covered with a new layer of geotextile joined to it by one of the methods mentioned above.

8 FIELD IDENTIFICATION AND TESTING

8.1 Quality assurance measures on site - basic principles

The aim of quality control is to ensure that geotextiles are used as planned, that they meet the quality requirements set for different application classes and that the work is carried out in a manner appropriate for long-term functioning of the geotextiles.

DEMANDS FOR THE SEPARATION LAYER

* Limit values as given in the specification list
* Construction site (specific application)
* Type of join

8.2 Material quality control

8.2.1 Type inspection

Type inspection on behalf of the purchaser (district organisation of the Finnish National Road Administration, contractor) involves establishing that a geotextile meets the quality requirements presented in Section 5.1.1, specified in Table 5.2 and further explained in Chapters 5.2 - 5.9.

The inspection test should be carried out in good time before the commencement of geotextile installation to ensure proper functioning of the geotextile at the site. Production quality control documents as required by ISO 9001 - 9003 may be utilized for the type inspection .

For type inspection a minimum of five samples, 0.6 * 0.6 m in size, should be taken from the rolls of each batch delivered to the construction site or to the central stock of a district organisation of the Finnish National Road Administration or from every 50 000 m^2 of geotextile. The samples should be taken at random in such a manner that they represent as well as possible the batches delivered to the construction site or to the central stock of a district organisation of the Finnish National Road Administration. It is the responsibility of the contractor to take the samples and to carry out the quality control measures as required. Further treatment of the samples and quality control testing should be carried out by an independent testing institute approved by the client.

8.2.2 Project-specific quality control during installation

The purpose of quality control during the actual installation of the geotextile is to ensure that the material employed at the site has been type-inspected, that it meets the quality requirements and is sufficiently homogeneous in quality.

A representative of the client should check all geotextile rolls as they arrive at the site. The client should have access to detailed data on the items concerned, i.e. type inspection results and a specimen.

Sampling

The quality of the material should be monitored both visually and by taking samples from the site

1) immediately upon commencement of installation,

2) at intervals of about 50,000 m^2 of geotextile in the course of the work (at least one sample being taken from each batch arriving at the site),

3) whenever defects in geotextile quality are observed or excessive fluctuation in quality is suspected.

The sampling data should be recorded on a form, which should be enclosed with the samples. The client or contractor should send the samples to an independent quality control institution for inspection and for quality control tests if inferior quality is suspected.

Storage of geotextiles on site

Geotextile rolls should be stored so as to ensure that the geotextile retains its original physical properties and is not damaged. Care should thus be taken to protect the rolls from UV radiation and from damage during storage or transportation. Storage conditions should be inspected in connection with sampling, paying special attention to:

- batch identification data: roll numbers, date and place of manufacture, supplier,
- storage time at the site,
- quantity stored,
- protection against light if stored for more than 1 month,
- protection against freezing (24 hours before installation),
- undamaged and homogeneous quality (visual inspection by random sampling at both ends of rolls).

Storage inspection data and any other observations should be recorded in a log-book and the site diary.

Installation procedure

The successful functioning of geotextiles requires the use of high quality material and appropriate installation. Great care should be taken to avoid damage during installation and unnecessary subgrade disturbance, and to ensure that geotextiles are placed as intended. In no case should traffic be allowed to run over unprotected geotextiles. For access traffic and hauling of material geotextiles should be covered by a protective layer at least 0.3 m thick. In geotextile applications serving permanent road constructions the thickness of the protective layer should be increased to 0.5 m without delay.

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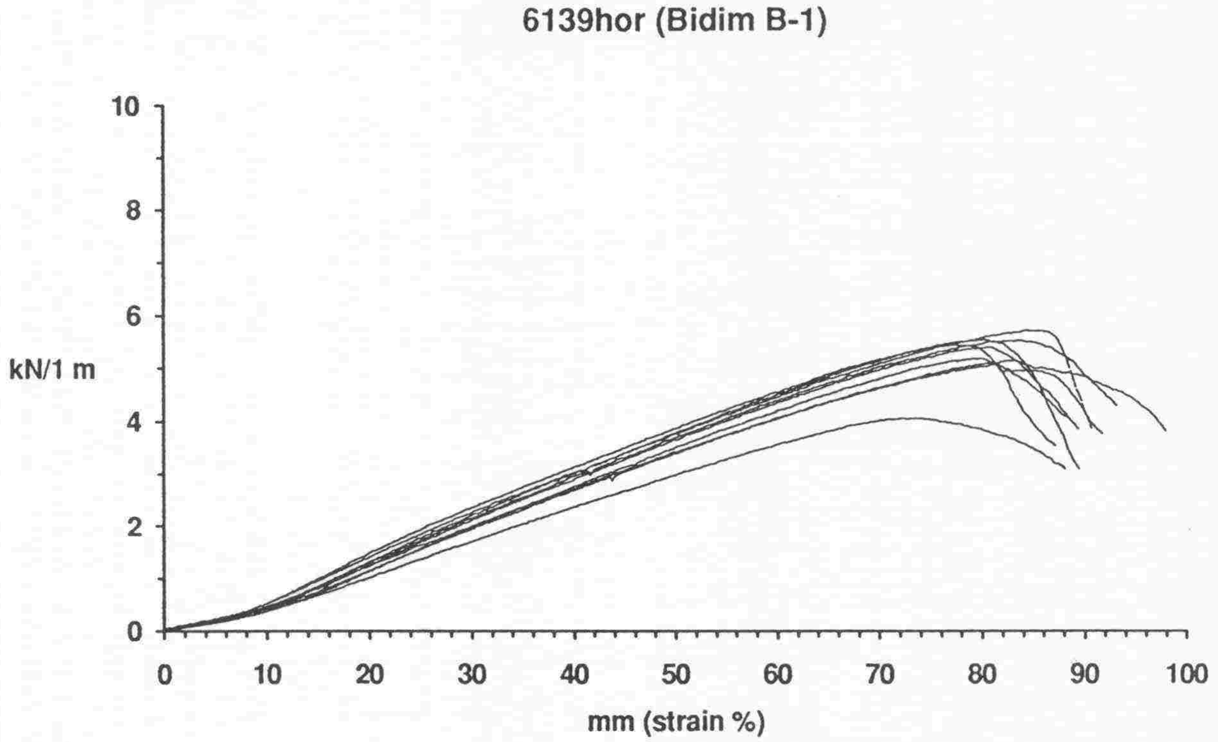
a)



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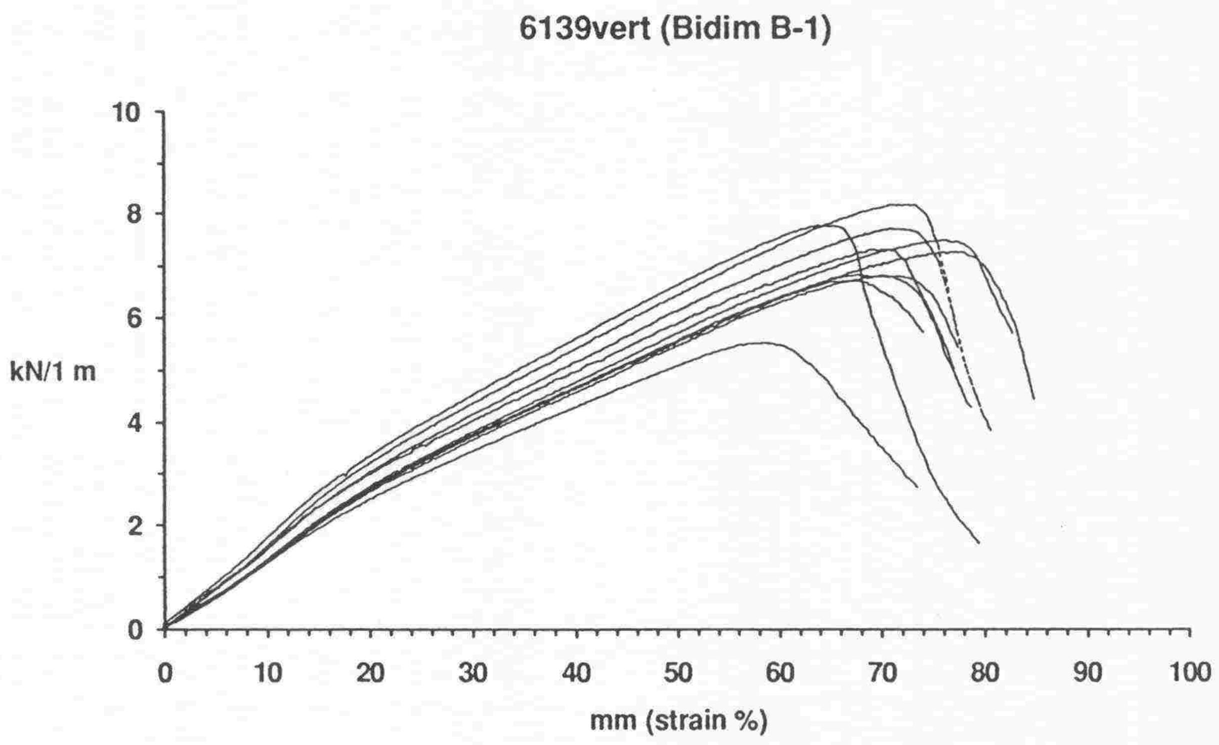
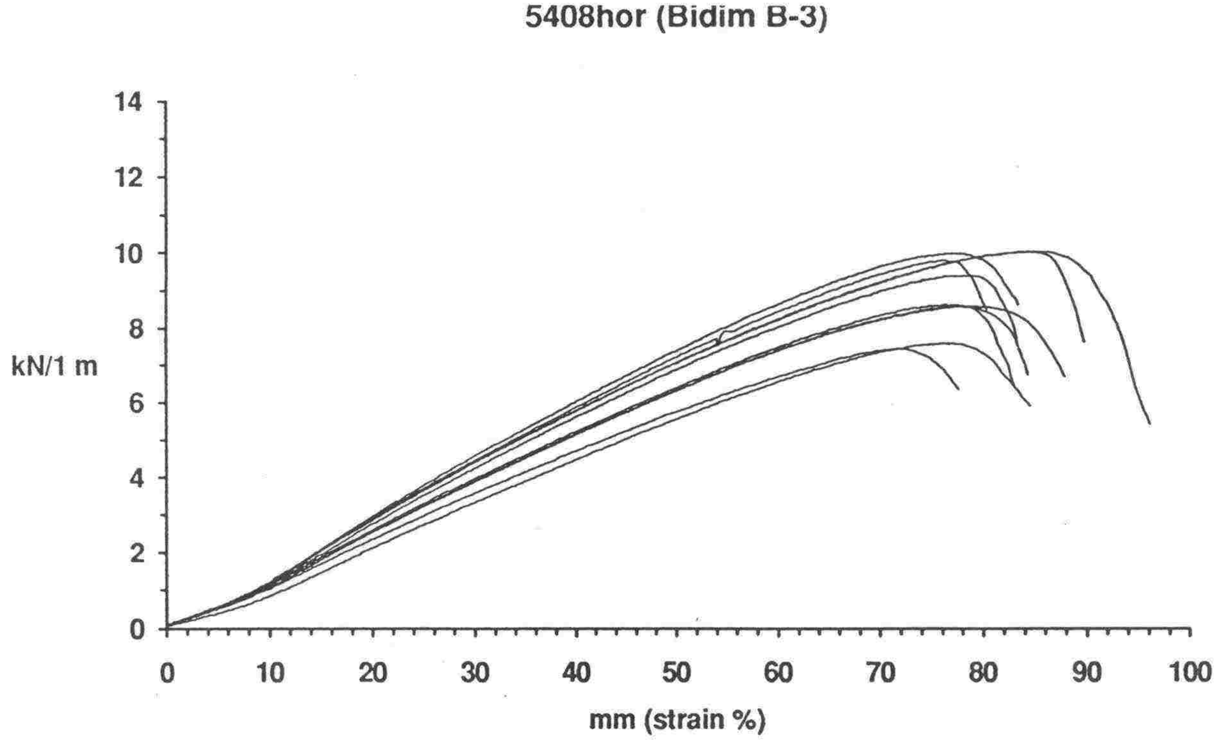


Fig.4.1 Wide width Tensile test (ISO 10 319) Geotextile type: BIDIM B-1 Lab.n:o 6139
a) Cross direction b) Machine direction

a)



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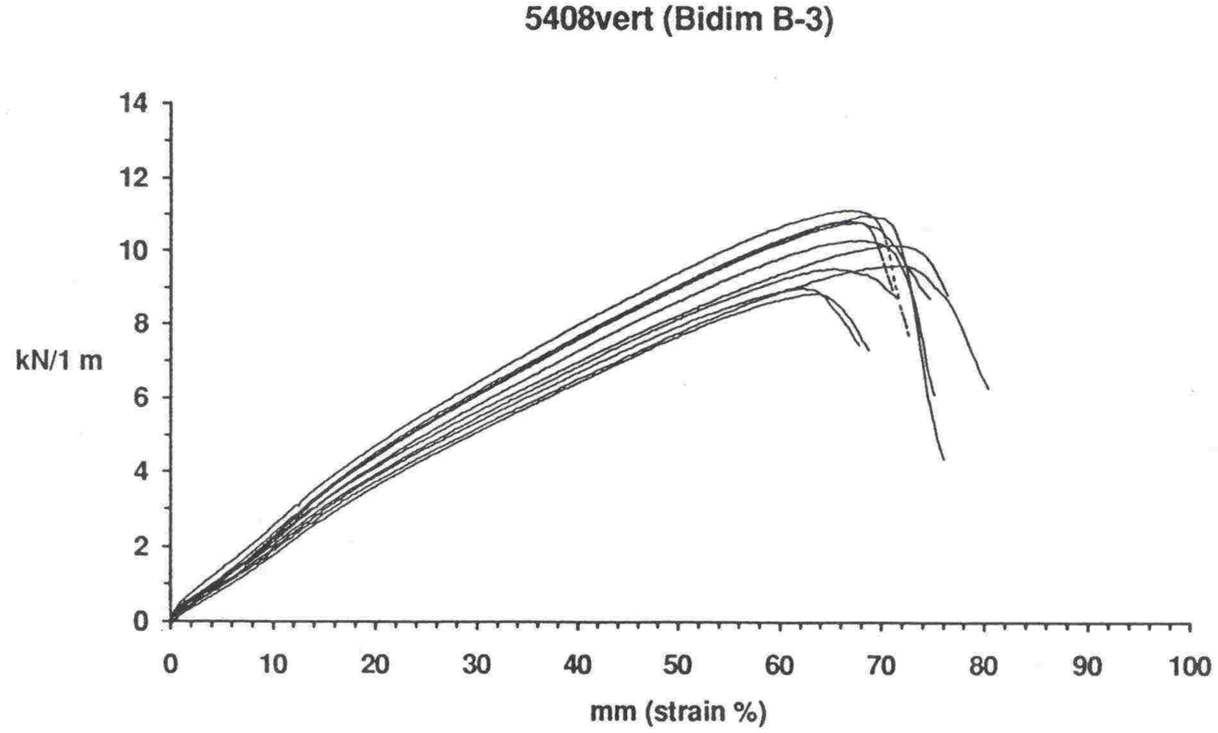
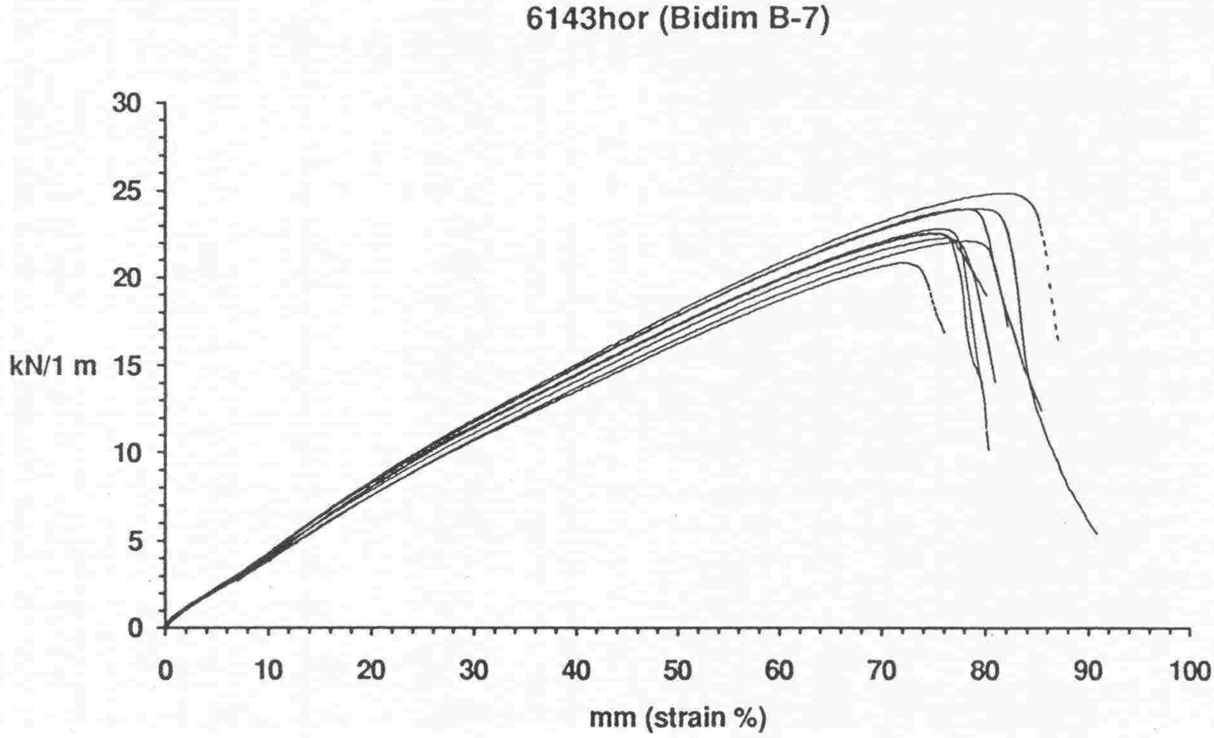


Fig.4.2 Wide width Tensile test (ISO 10 319) Geotextile type: BIDIM B-3 Lab.n:o 5408
a) Cross direction b) Machine direction

a)



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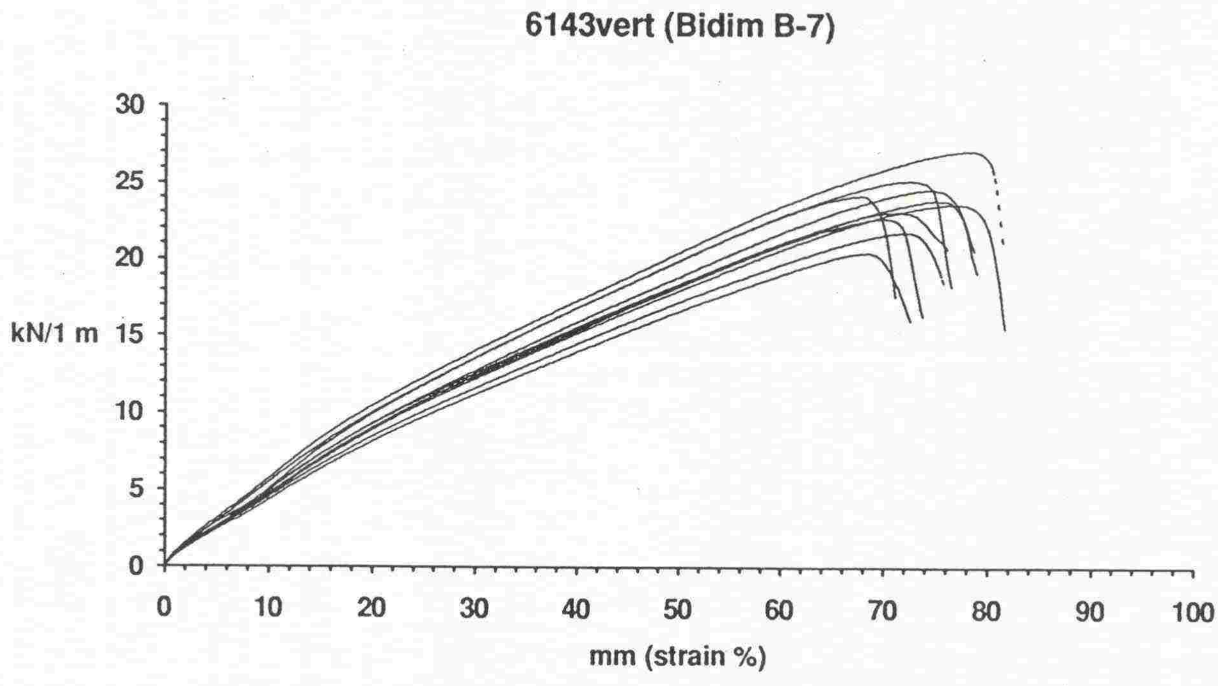
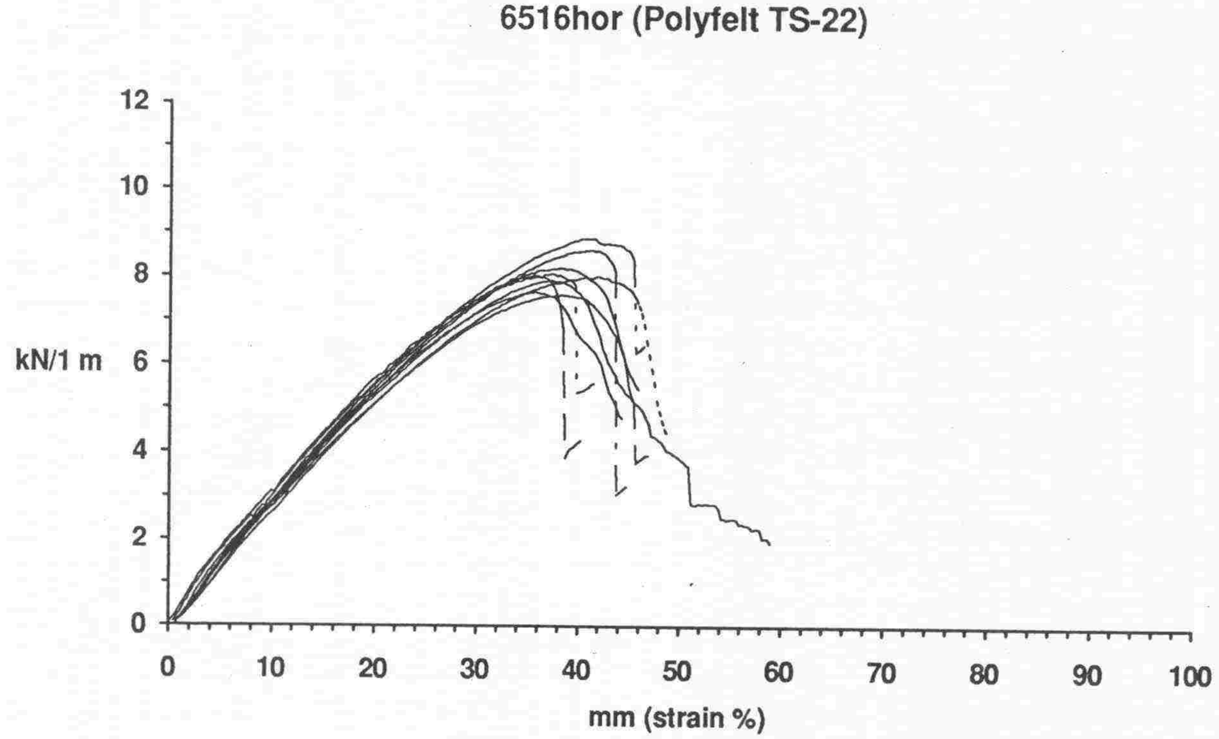


Fig.4.3 Wide width Tensile test (ISO 10 319) Geotextile type: BIDIM B-7 Lab.n:o 6143
a) Cross direction b) Machine direction

a)



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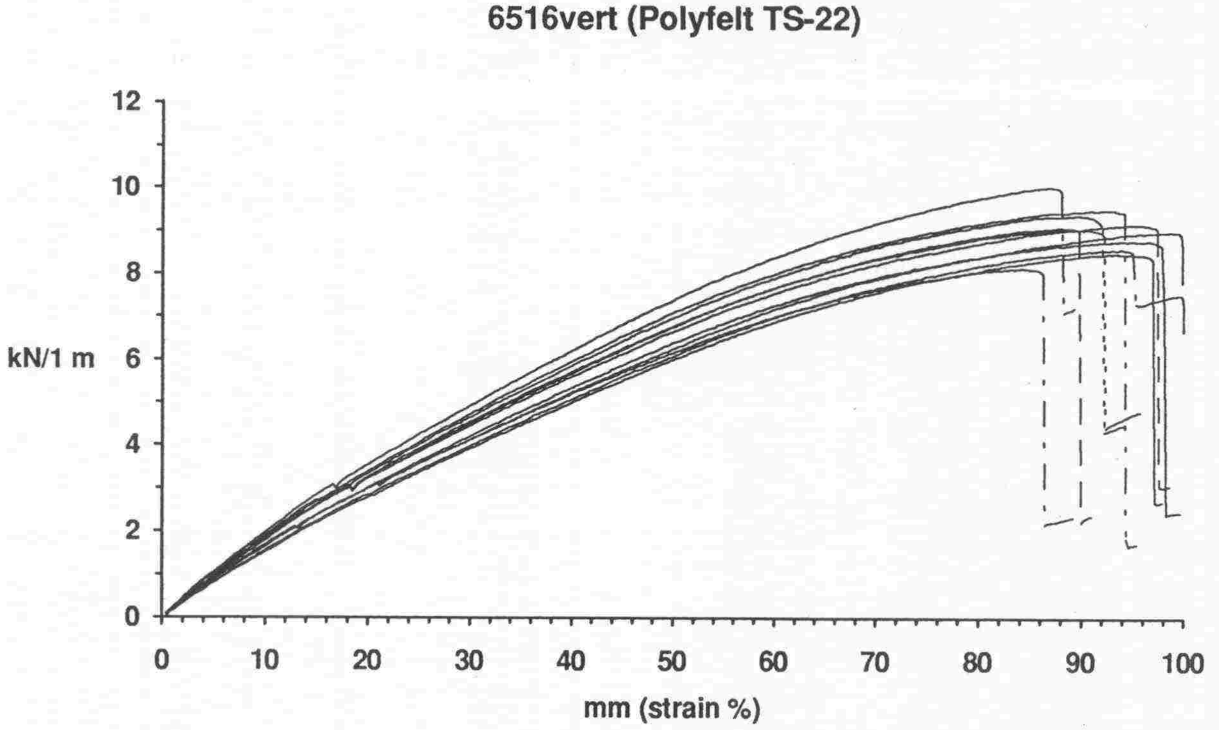
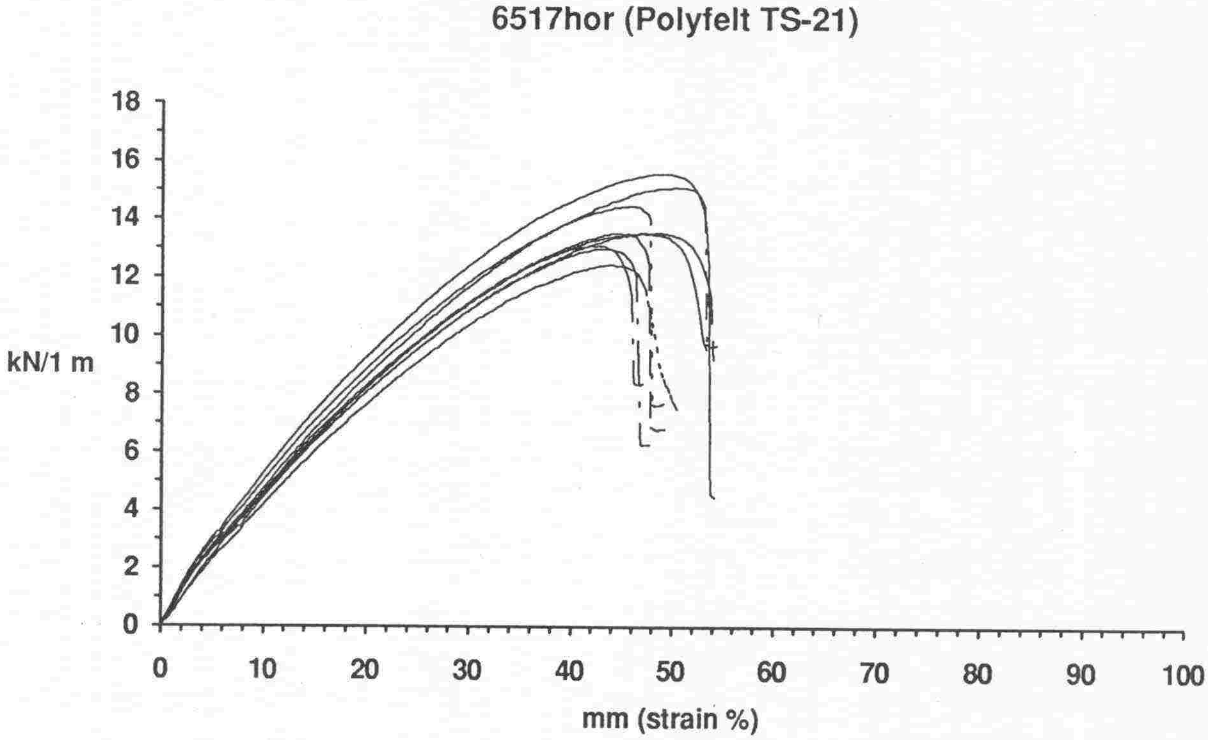


Fig.4.4 Wide width Tensile test (ISO 10 319) Geotextile type: Polyfelt TS-22 Lab.n:o 6516
a) Cross direction b) Machine direction

a)



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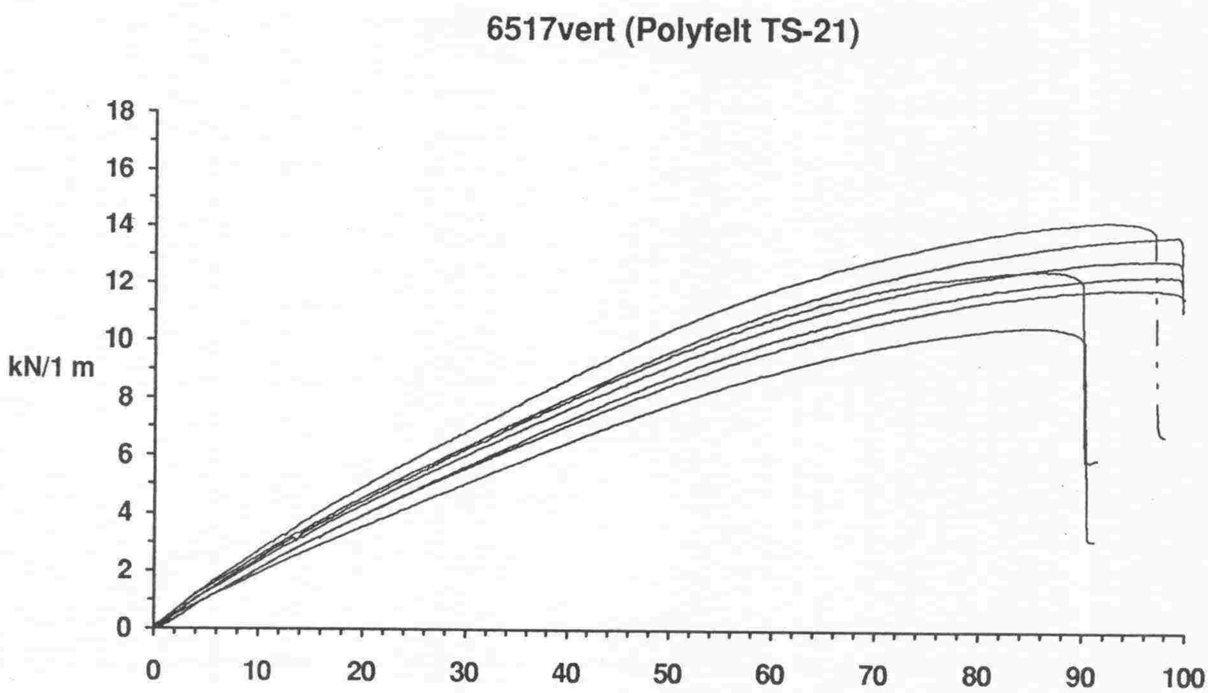
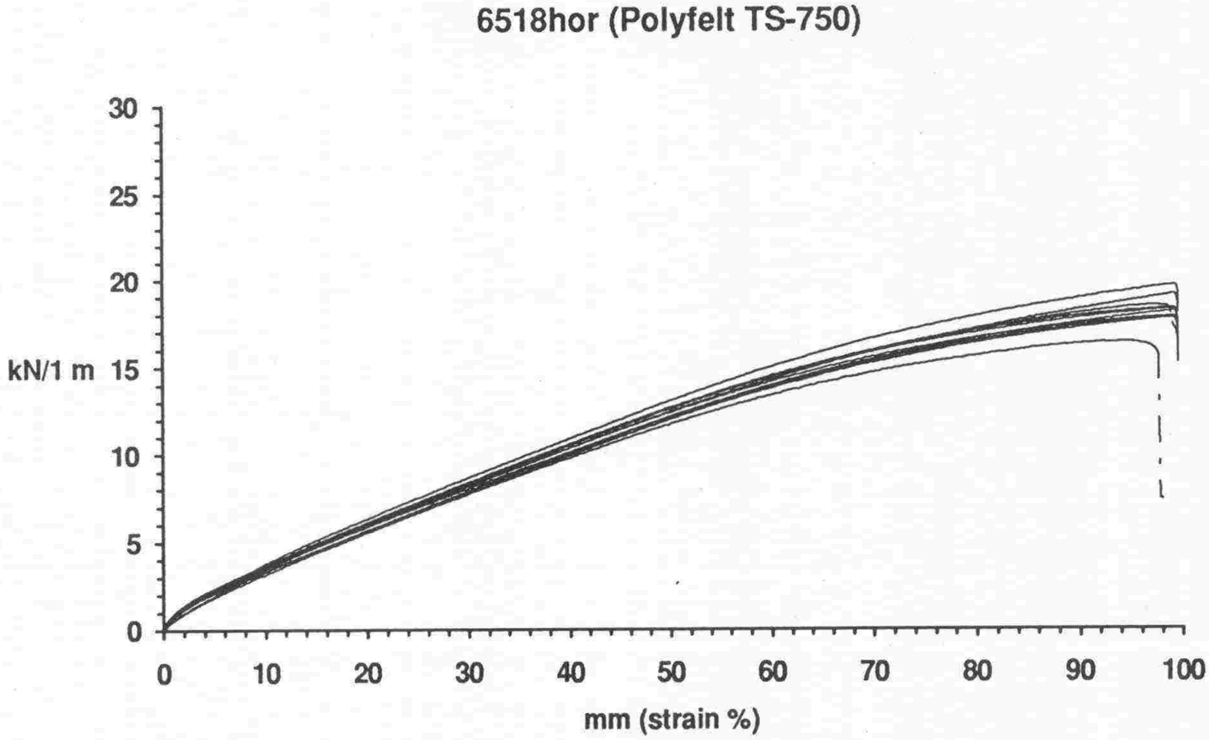


Fig.4.5 Wide width Tensile test (ISO 10 319) Geotextile type: Polyfelt TS-21 Lab.n:o 6517
a) Cross direction b) Machine direction

a)



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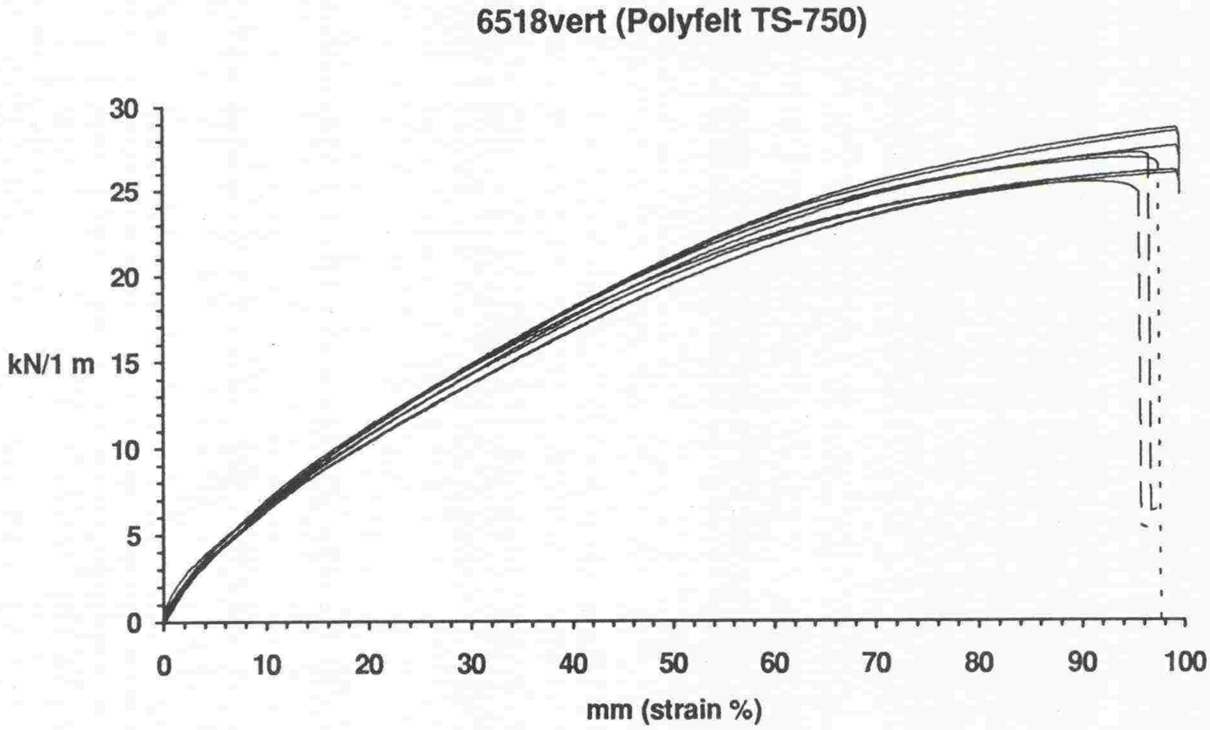
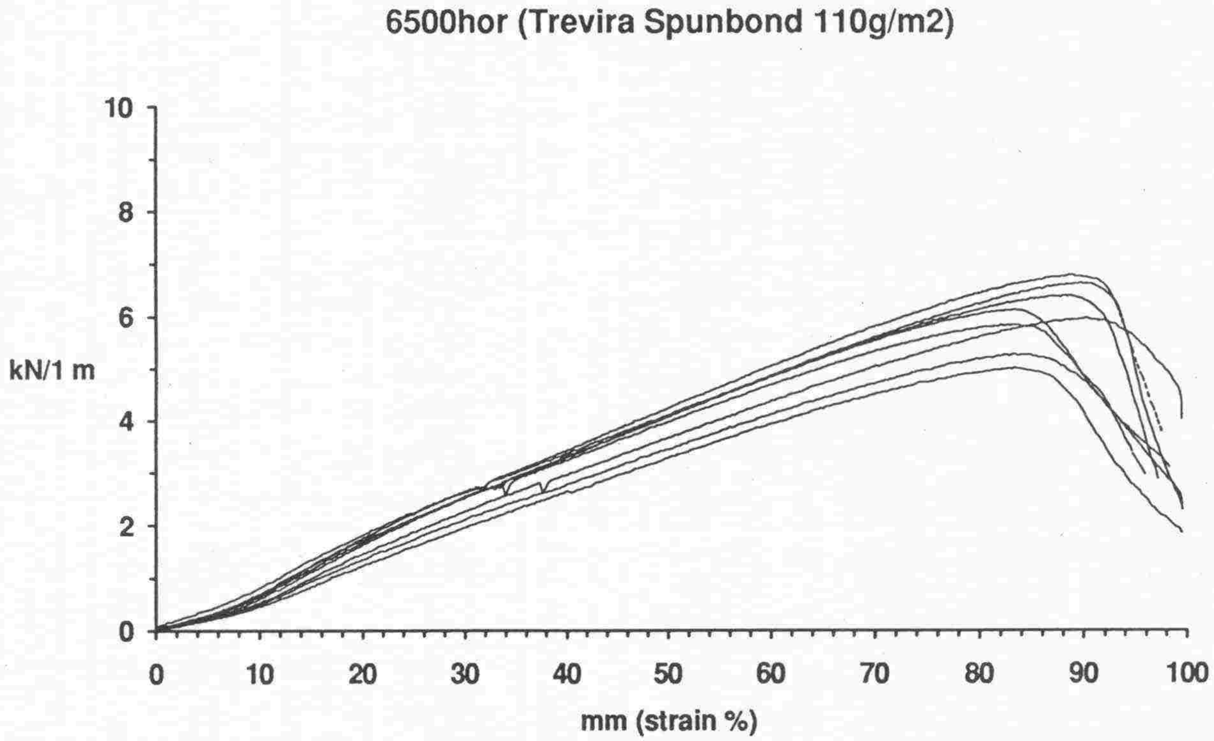


Fig.4.6 Wide width Tensile test (ISO 10 319) Geotextile type: Polyfelt TS-750 Lab.n:o 6518
a) Cross direction b) Machine direction

a)



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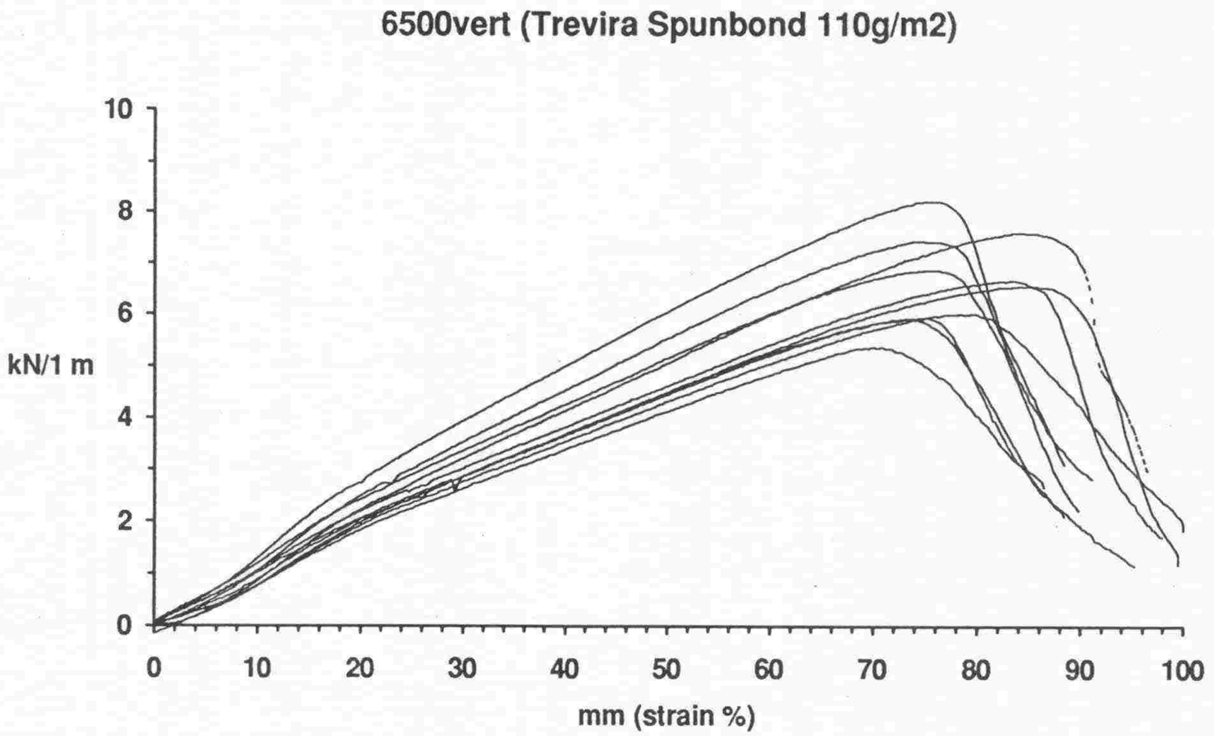
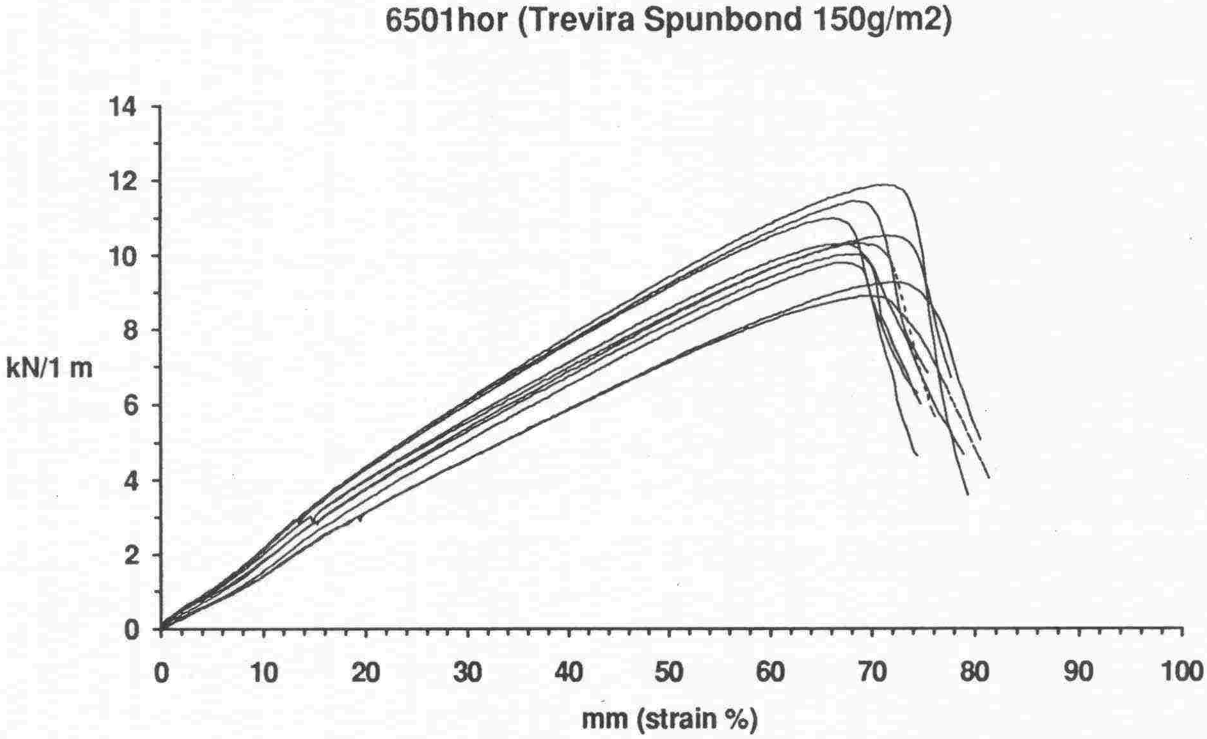


Fig.4.7 Wide width Tensile test (ISO 19 319). Geotextile type: Trevira Spunbond 110g/m^2
Lab.n:o 6500. a) Cross direction b) Machine direction

a)



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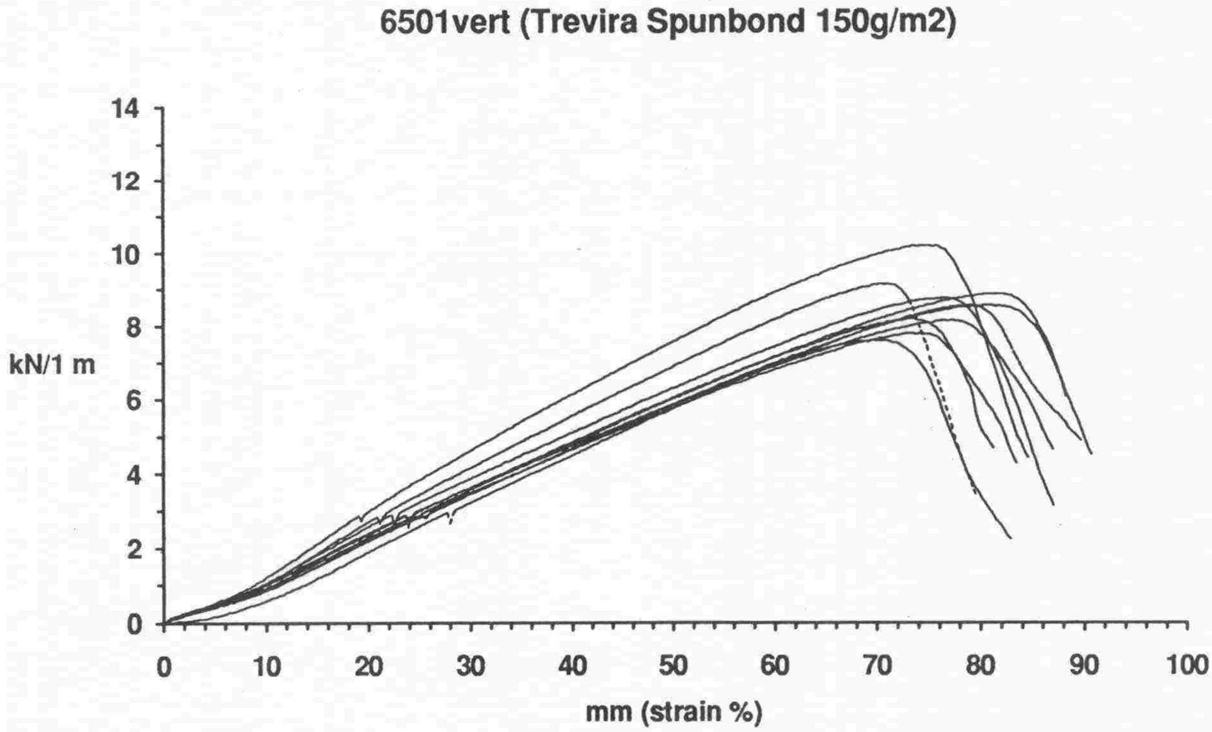
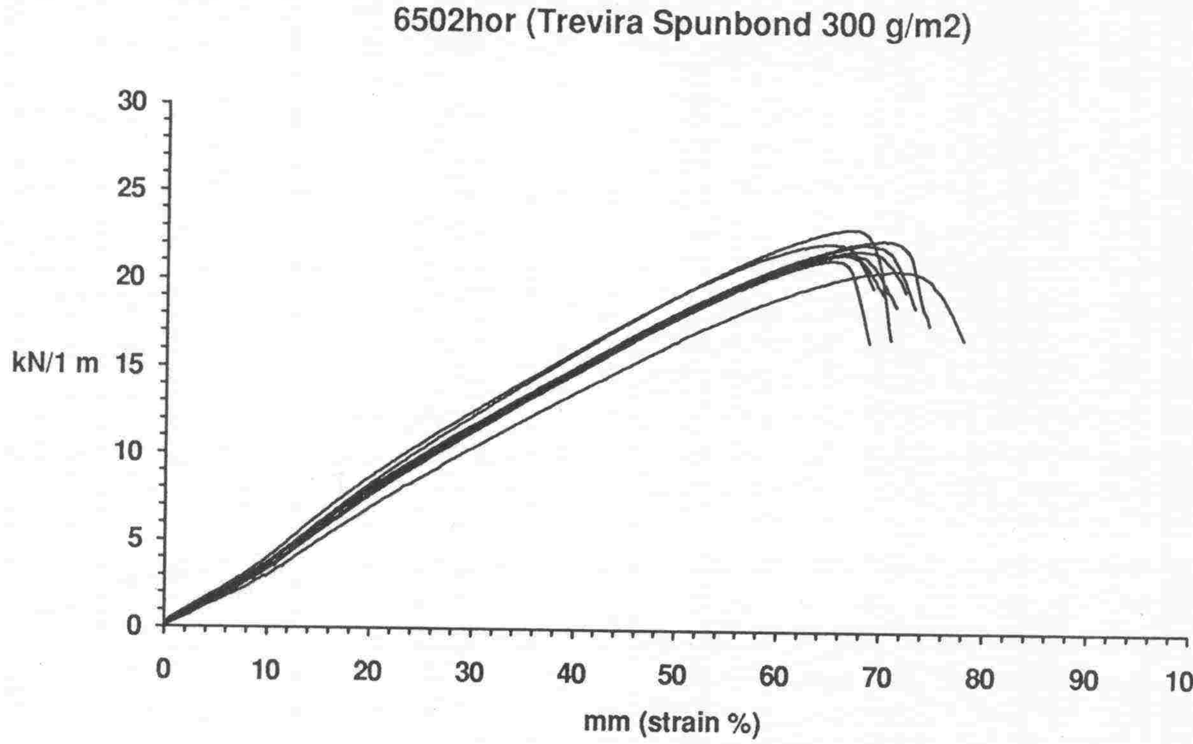


Fig.4.8 Wide width Tensile test (ISO 10 319) Geotextile type: Trevira Spunbond 150g/m^2
Lab.n:o 6501 a) Cross direction b) Machine direction

a)



b)

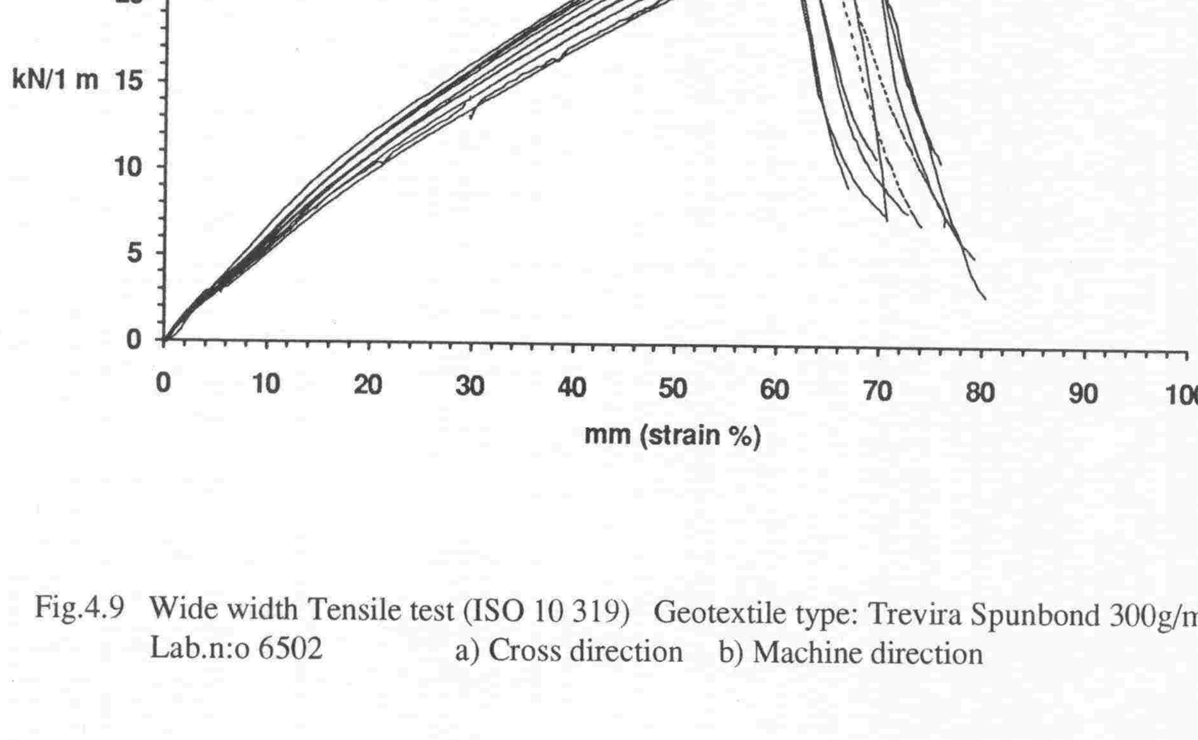
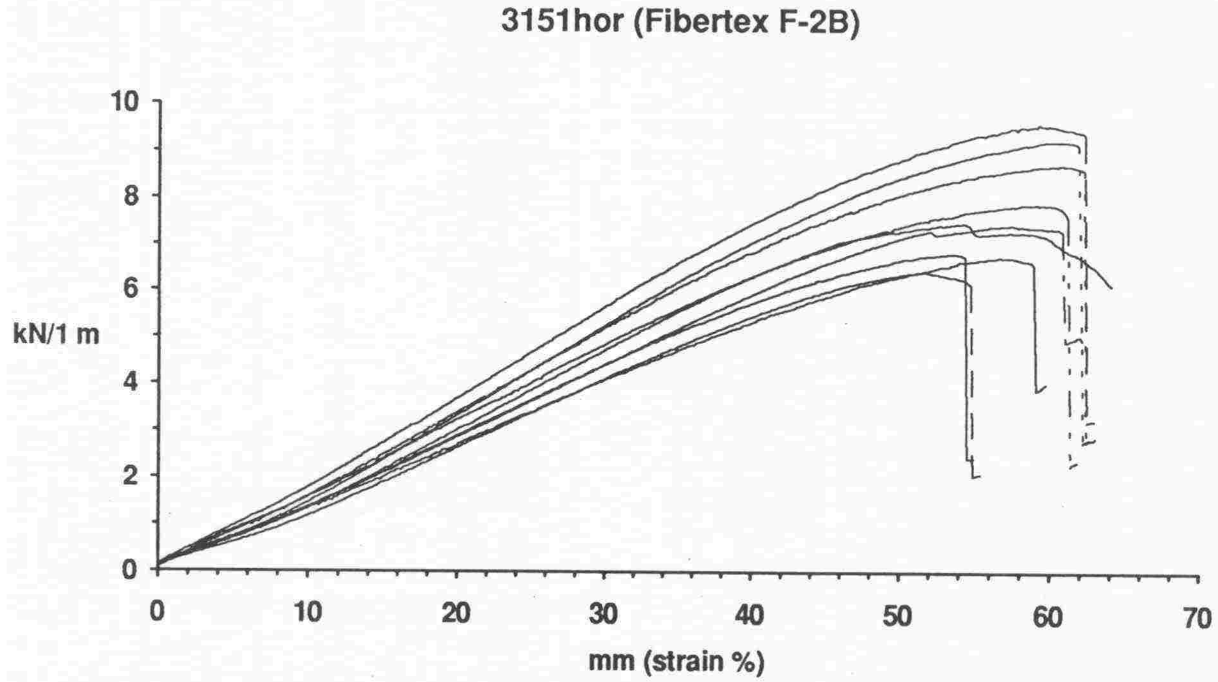


Fig.4.9 Wide width Tensile test (ISO 10 319) Geotextile type: Trevira Spunbond 300g/m²
Lab.n:o 6502 a) Cross direction b) Machine direction

a)



b)

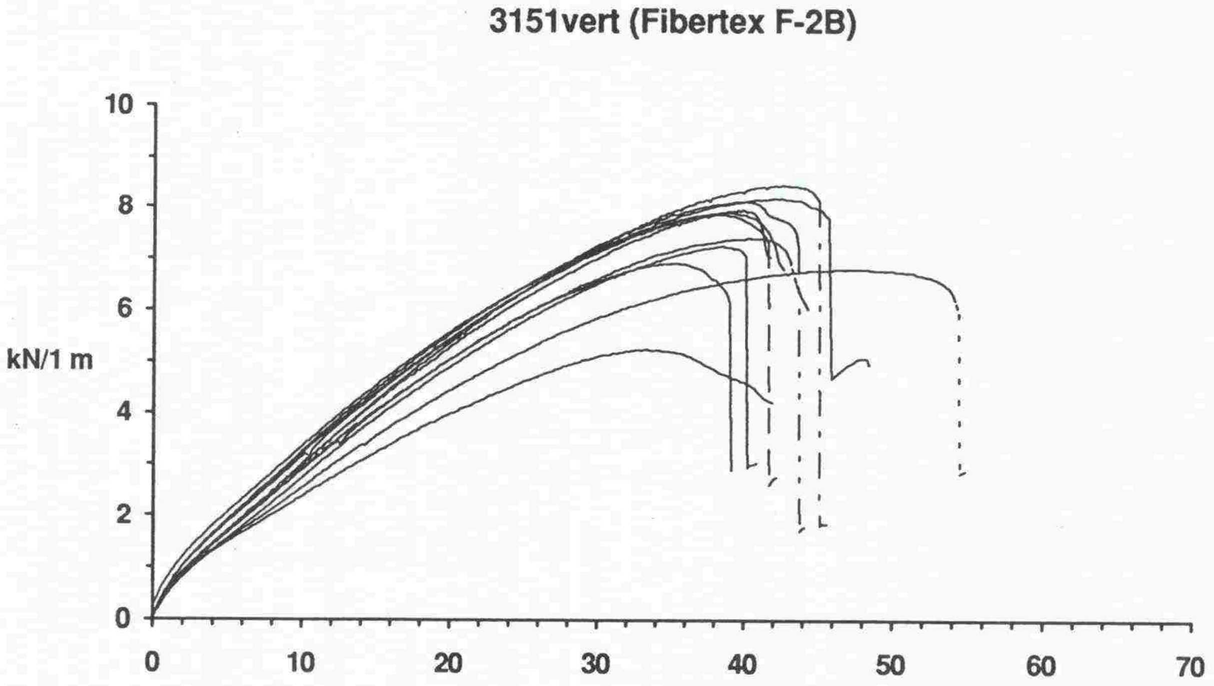
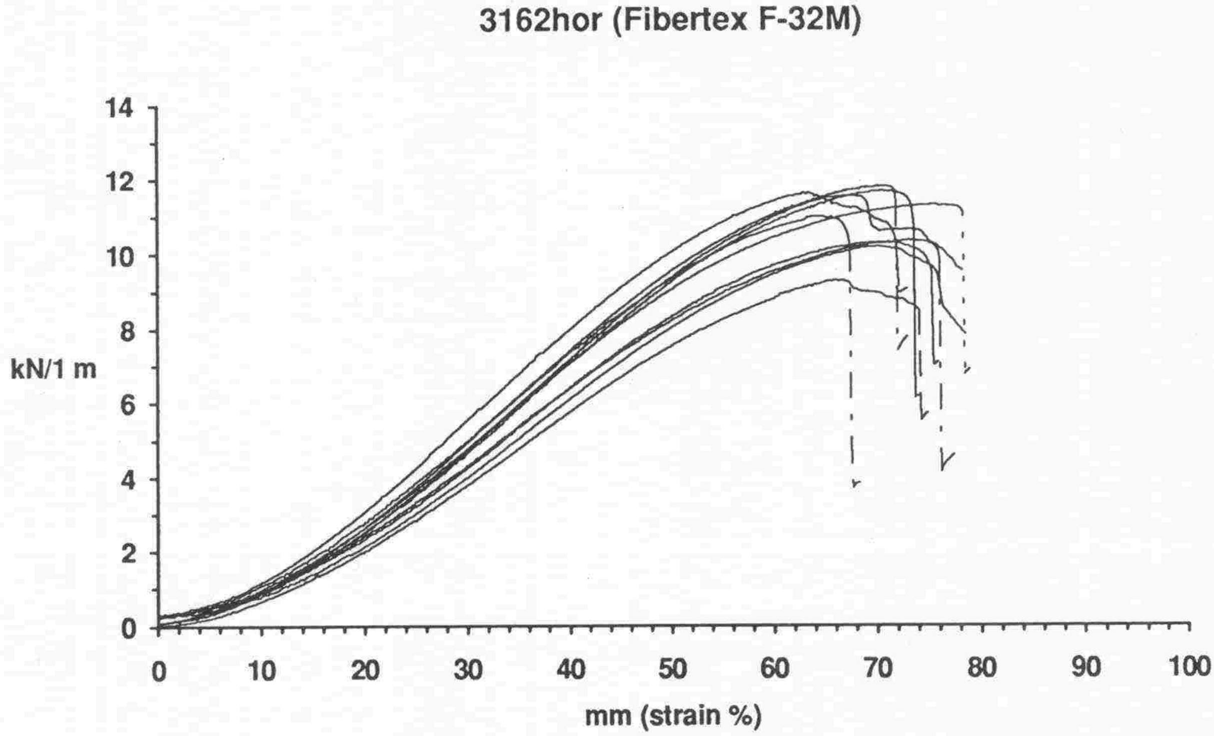


Fig.4.10 Wide width Tensile test (ISO 10 319) Geotextile type: Fibertex F-2B Lab.n:o 3151
a) Cross direction b) Machine direction

a)



b)

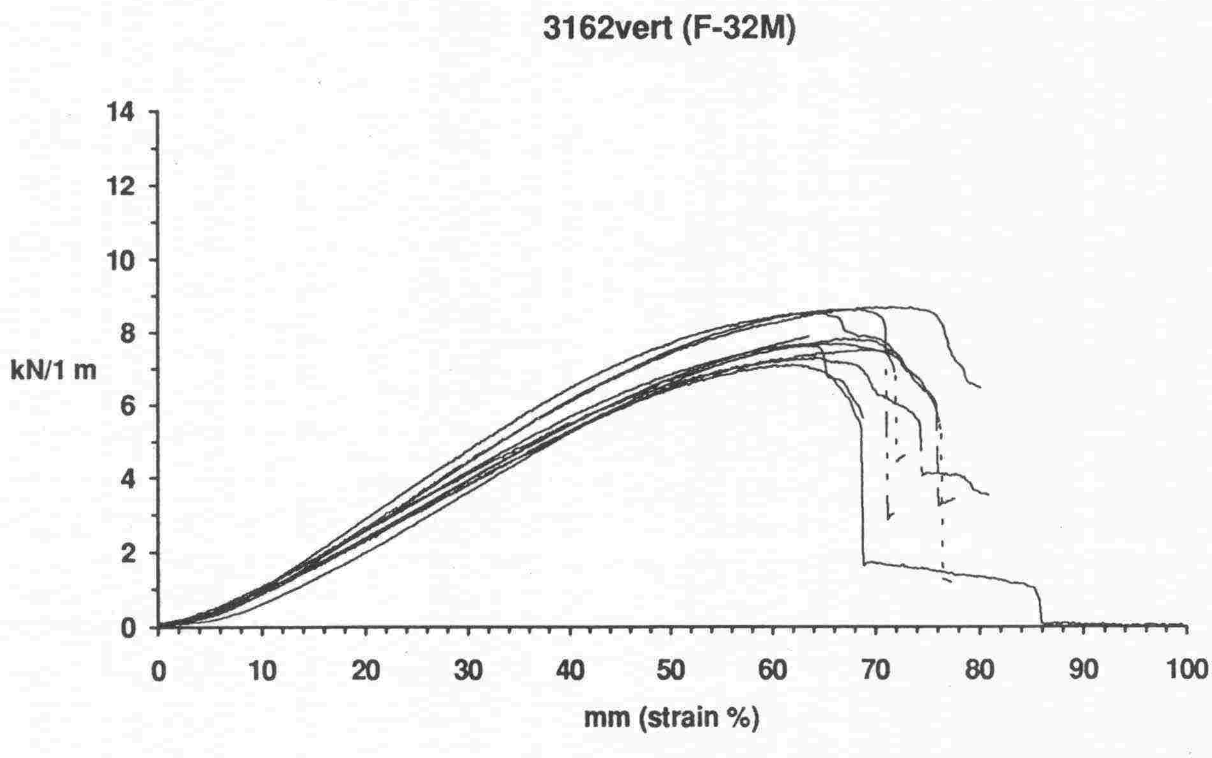
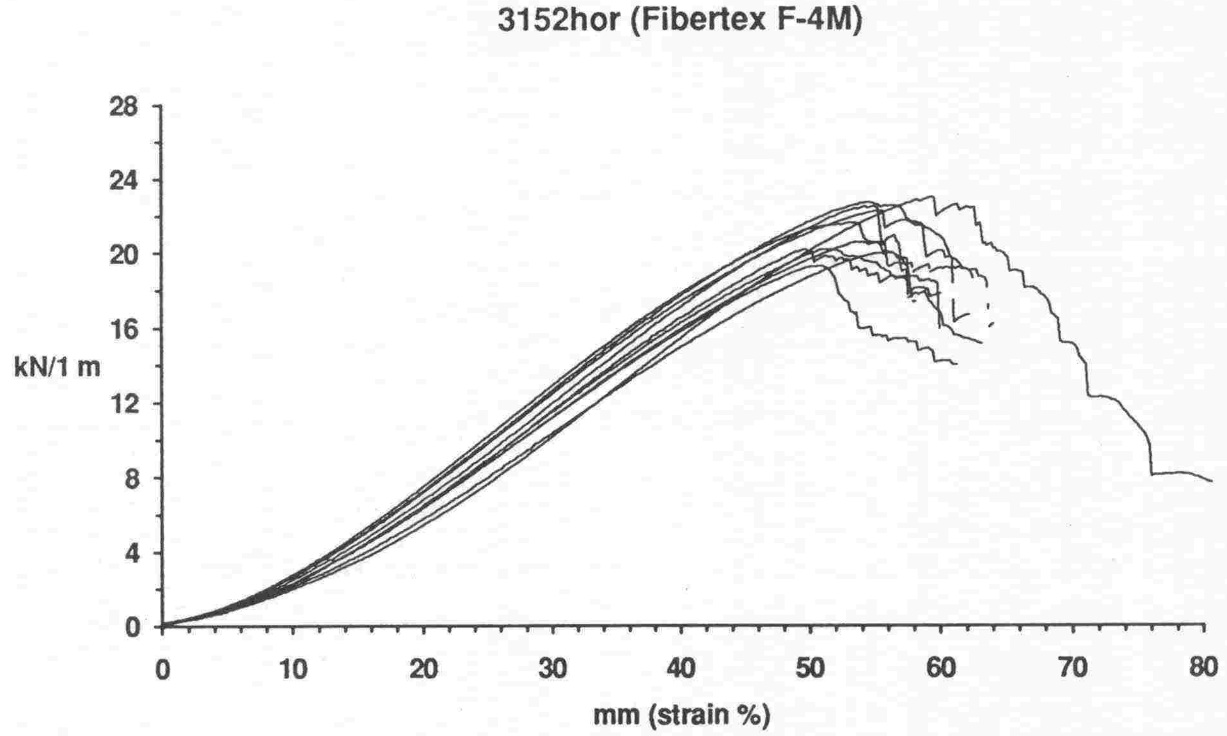


Fig.4.11 Wide width Tensile test (ISO 10 319) Geotextile type: Fibertex F-32M Lab.n:o 3162
a) Cross direction b) Machine direction

a)



b)

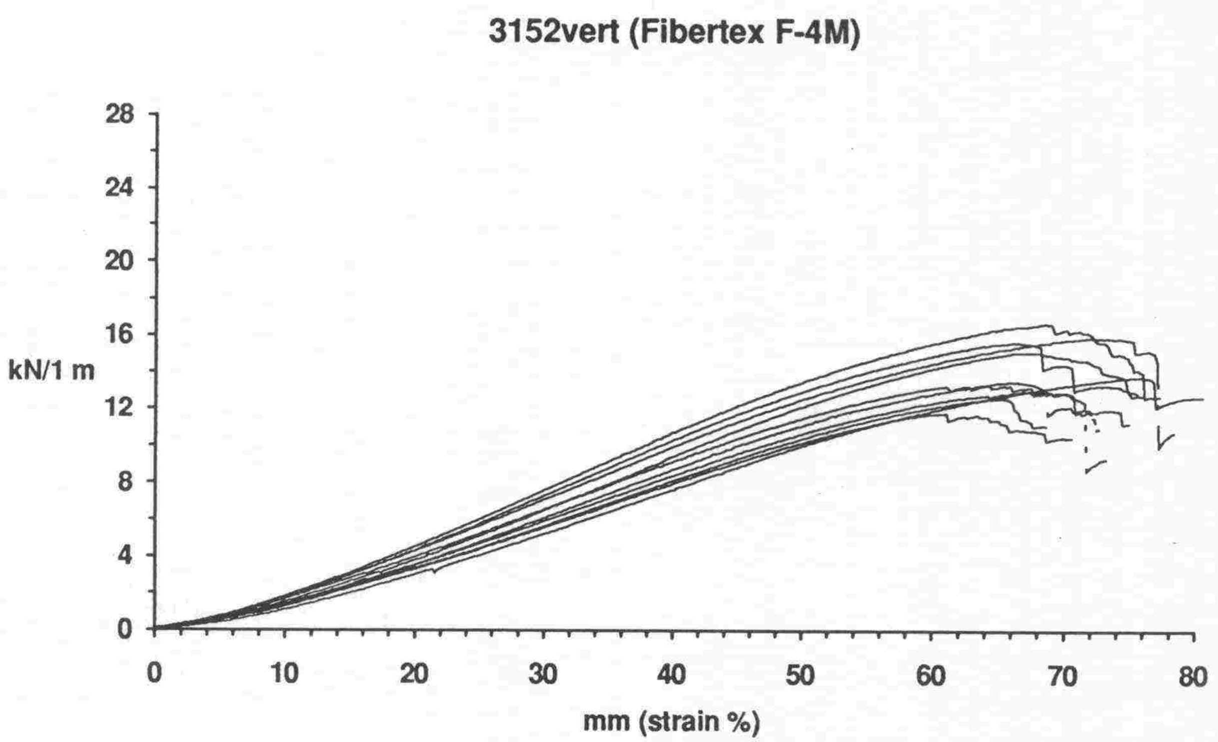
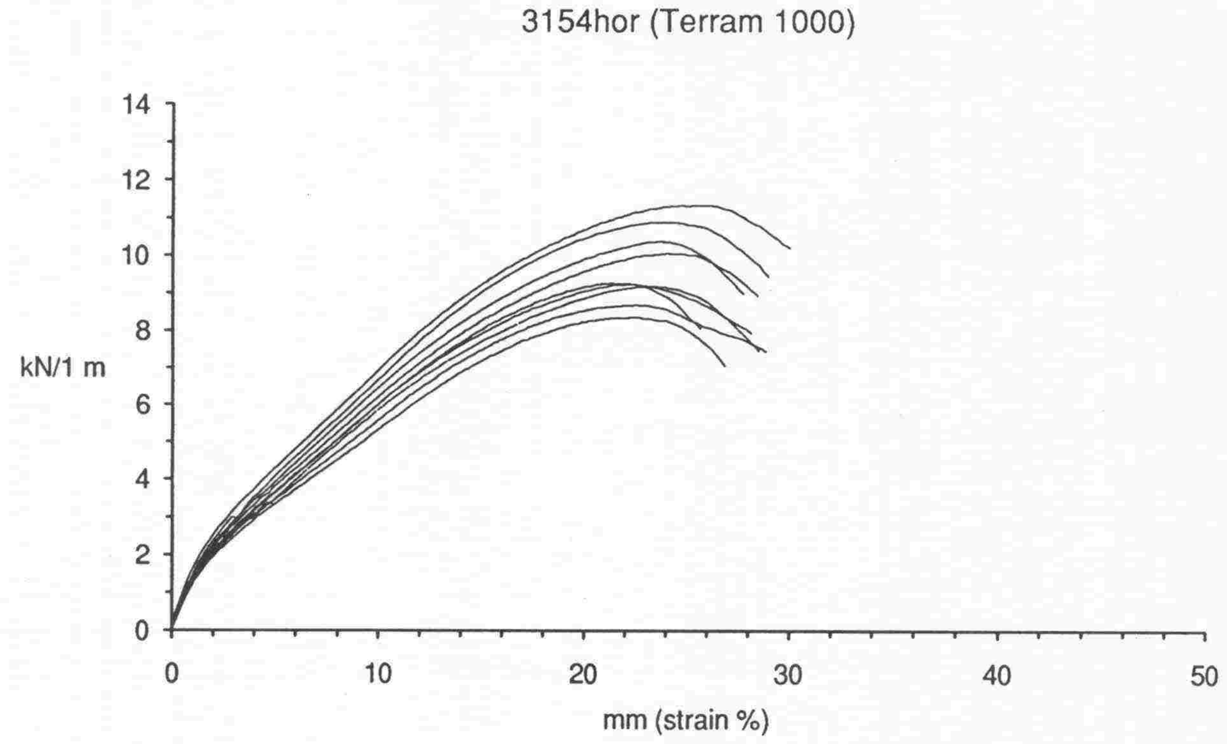


Fig.4.12 Wide width Tensile test (ISO 10 319) Geotextile type: Fibertex F-4M Lab.n:o 3152
a) Cross direction b) Machine direction

a)



b)

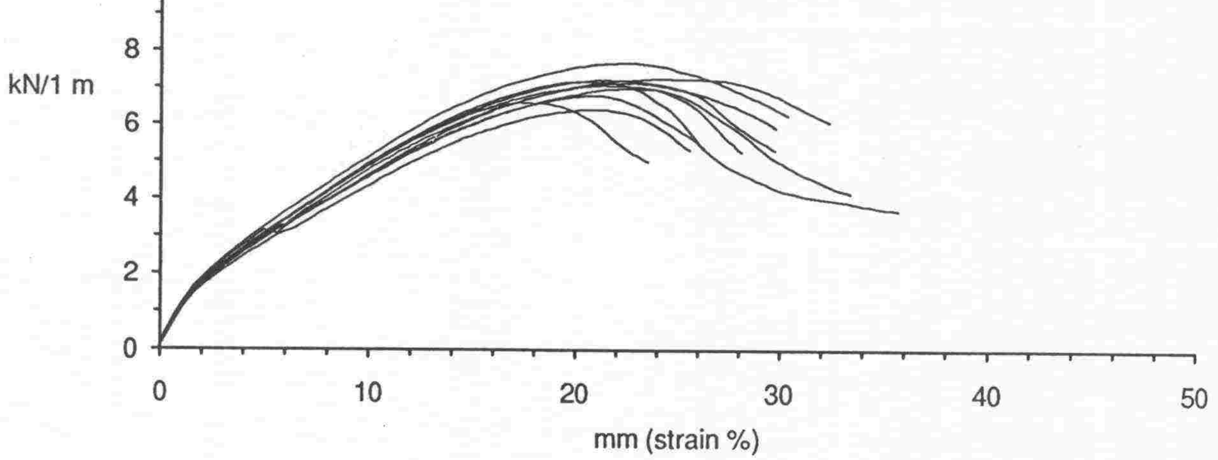
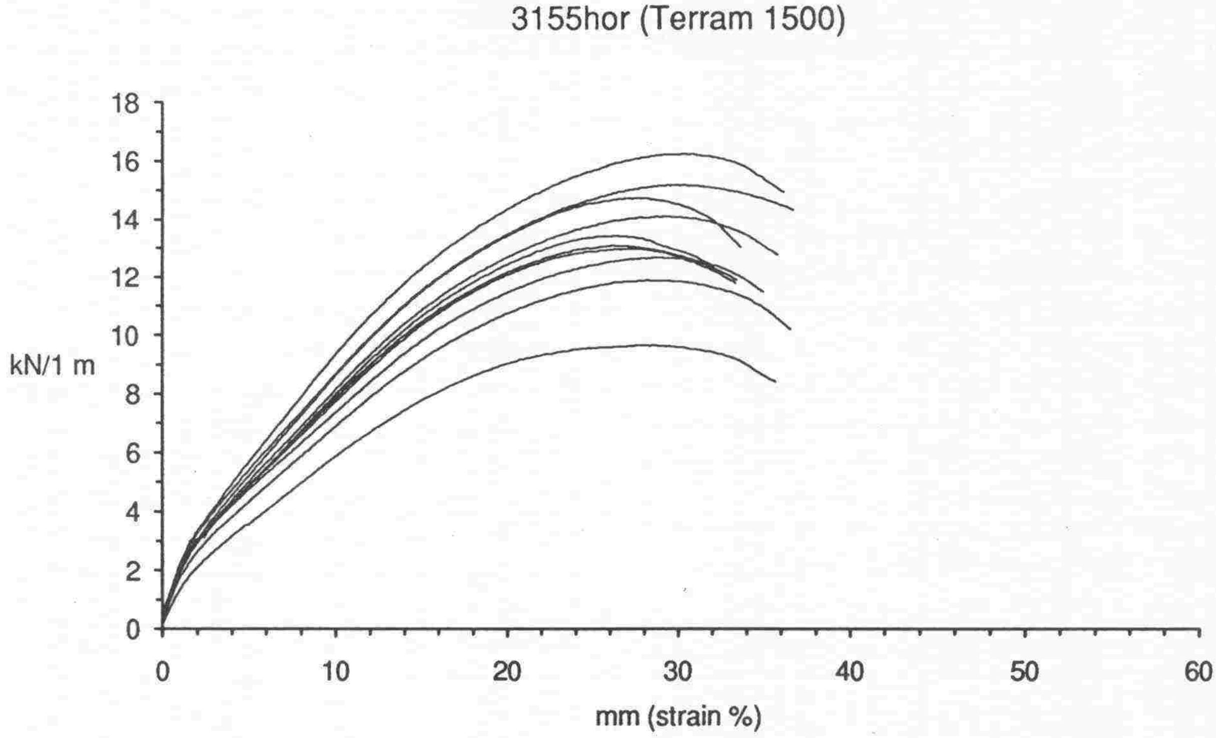


Fig.4.13 Wide width Tensile test (ISO 10 319) Geotextile type: Terram 1000 Lab.n:o 3154
a) Cross direction b)Machine direction

a)



b)

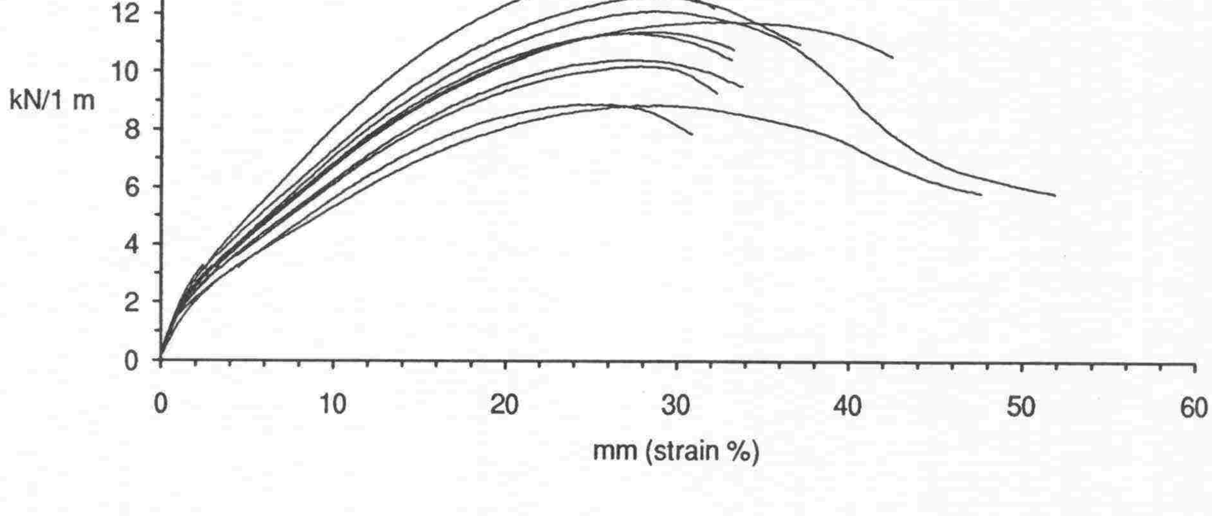
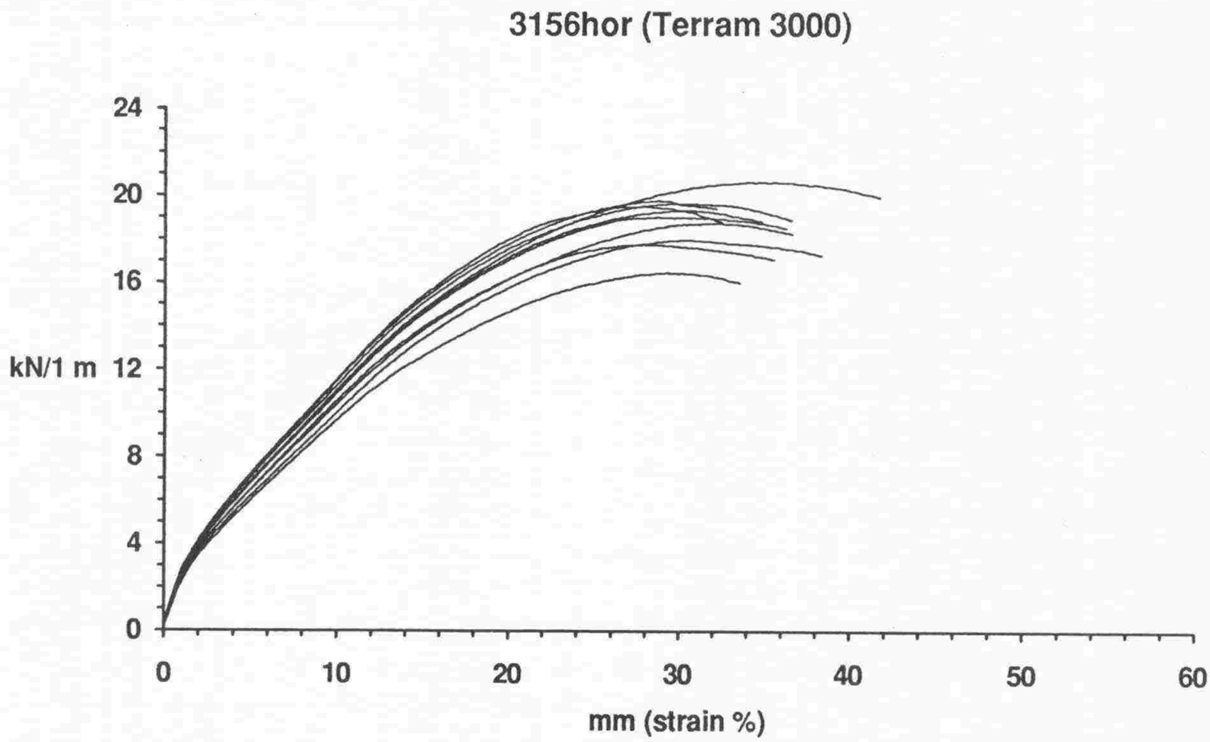


Fig.4.14 Wide width Tensile test (ISO 10 319) Geotextile type: Terram 1500 Lab.n:o 3155
a) Cross direction b) Machine direction

a)



b)

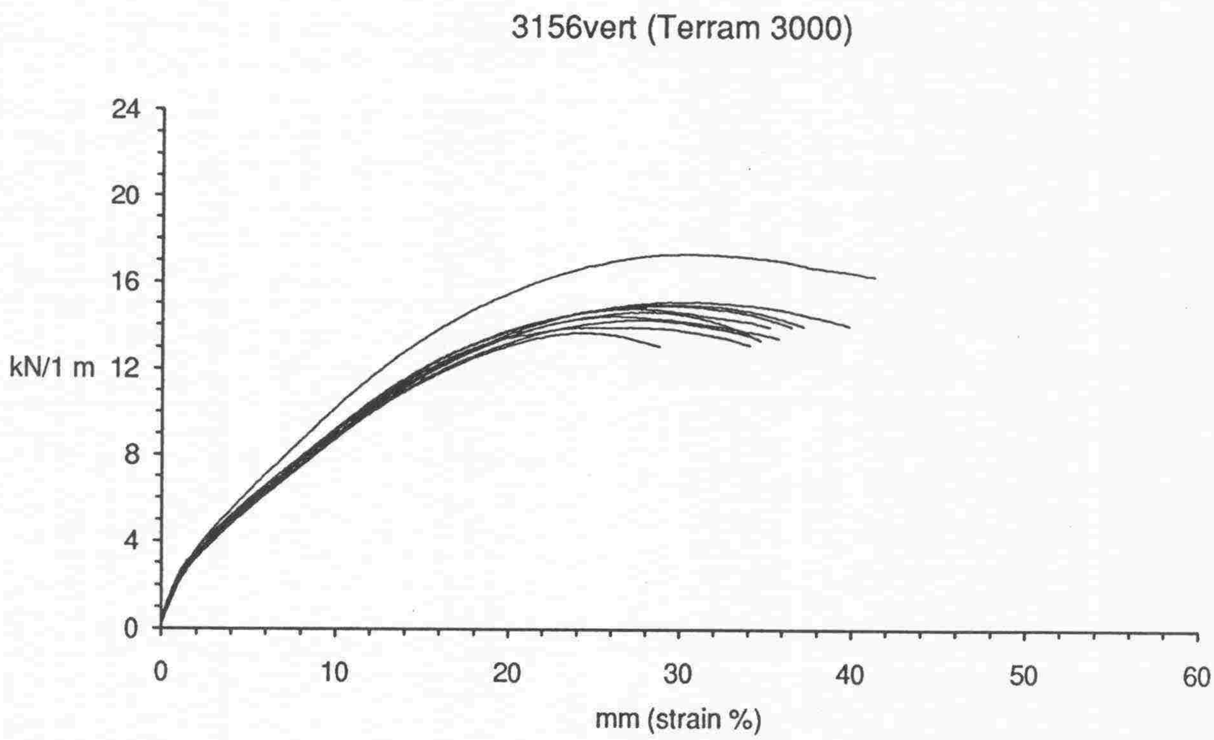
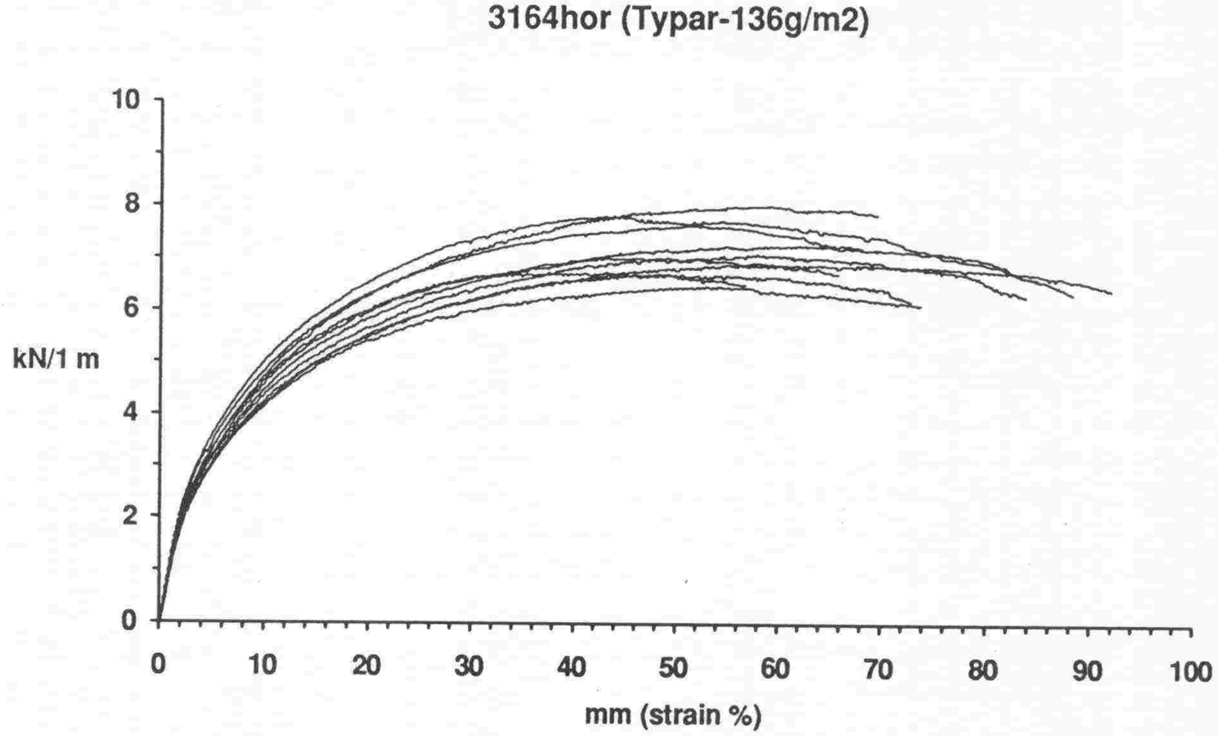


Fig.4.15 Wide width Tensile test (ISO 10 319) Geotextile type: Terram 3000 Lab.n:o 3156
a) Cross direction b) Machine direction

a)



b)

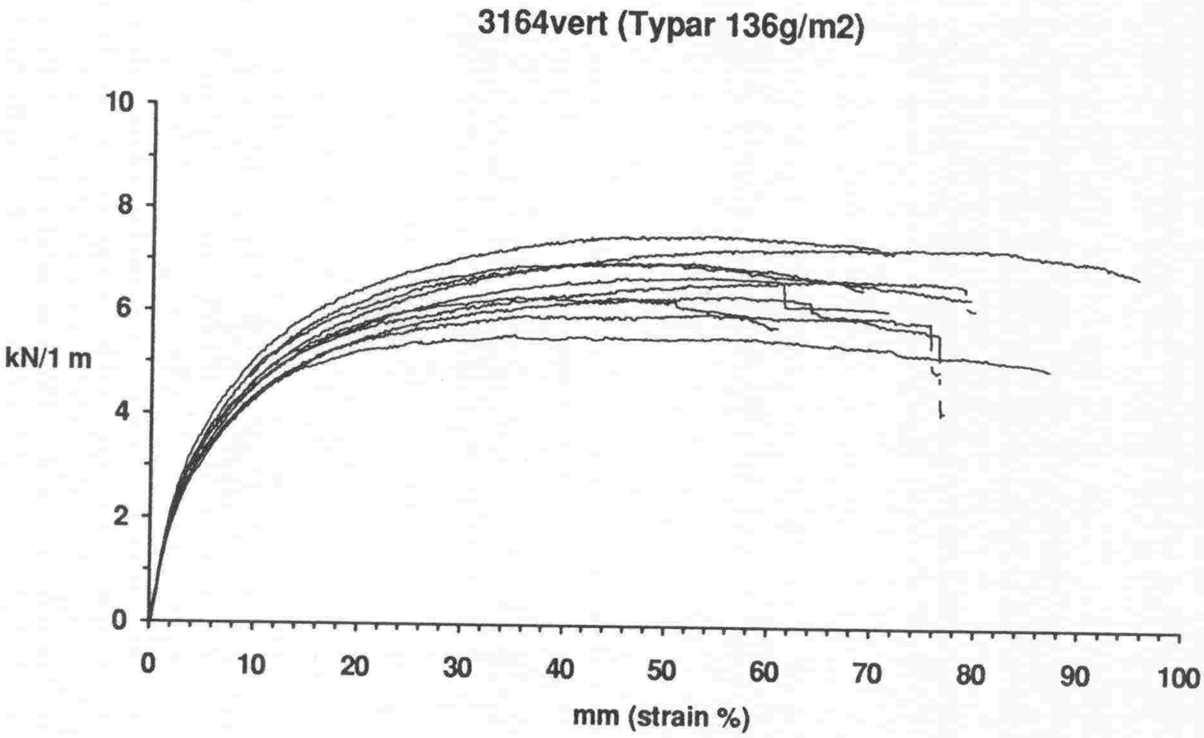
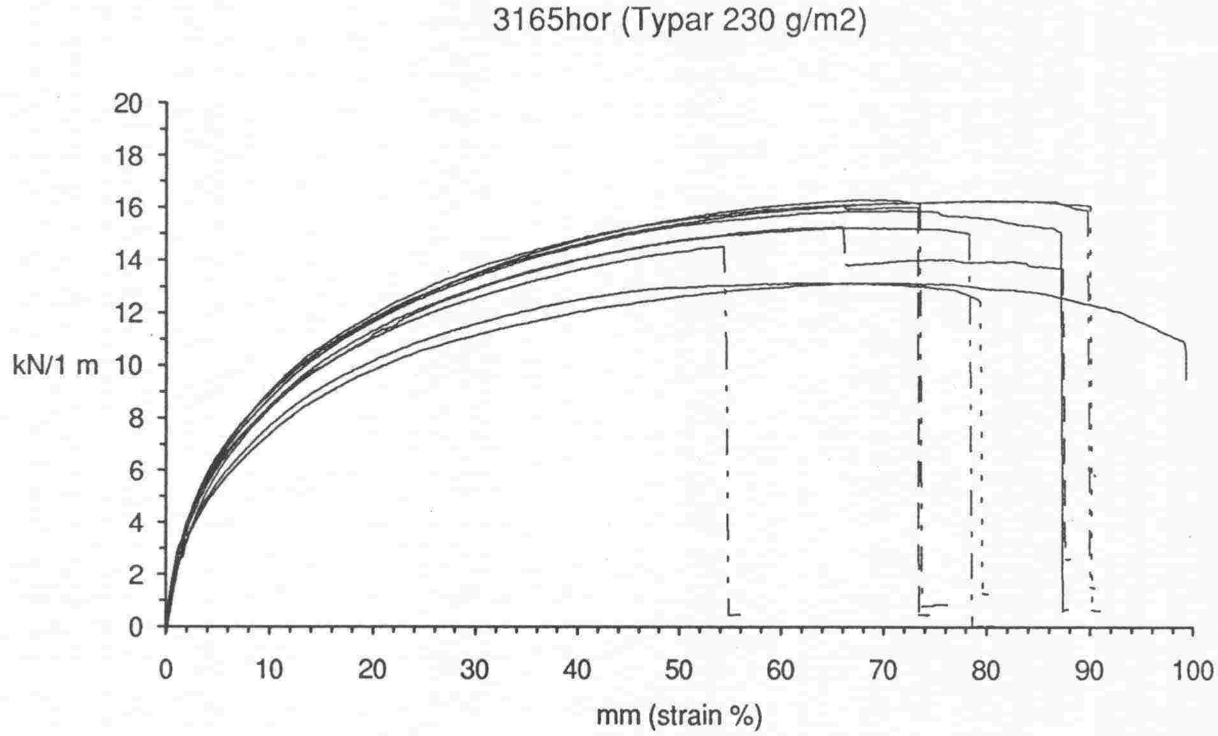


Fig.4.16 Wide width Tensile test (ISO 10 319) Geotextile type: Typar-136 g/m^2
Lab.n:o 3164 a) Cross direction b) Machine direction

a)



b)

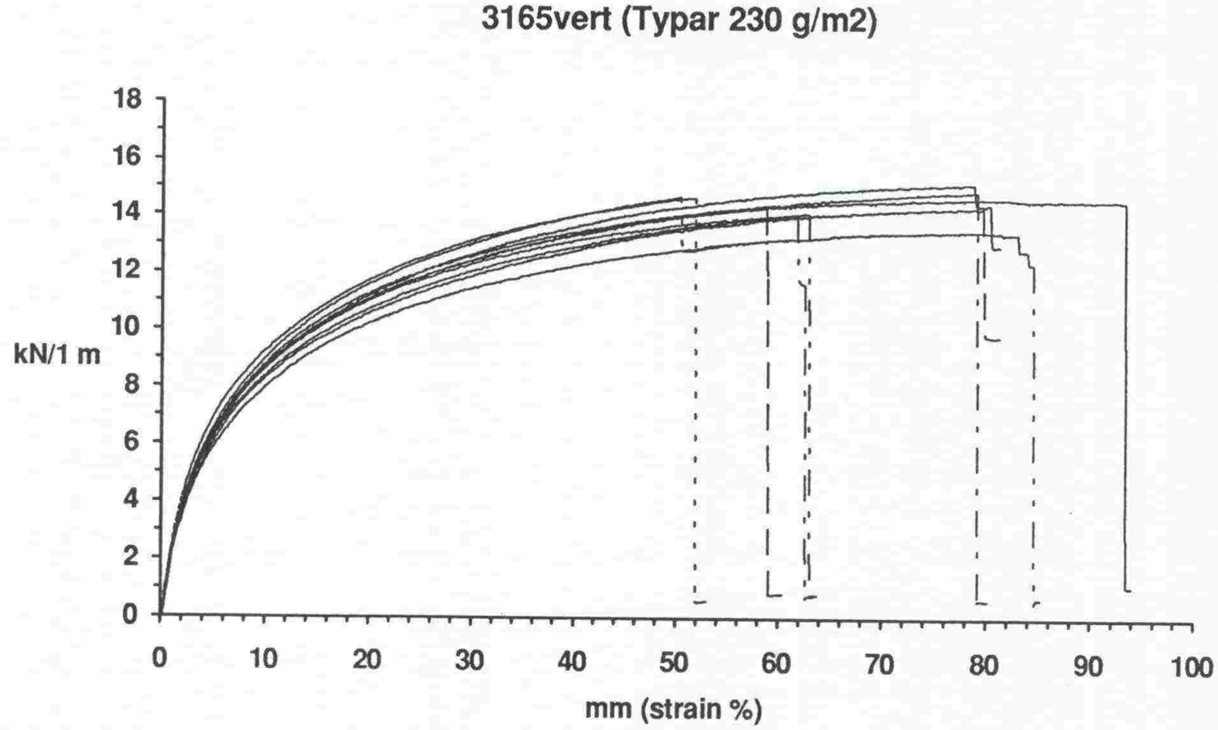
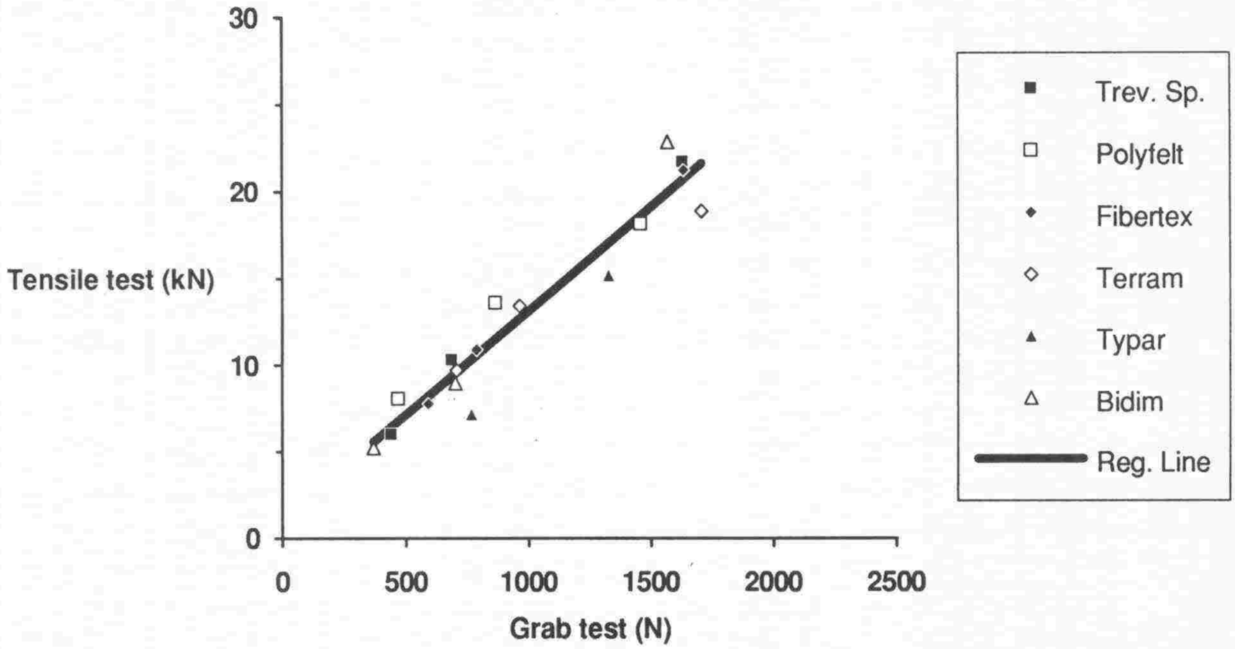


Fig.4.17 Wide width Tensile test (ISO 10 319) Geotextile type: Typar-230 g/m^2
Lab.n:o 3165 a) Cross direction b) Machine direction

a)



b)

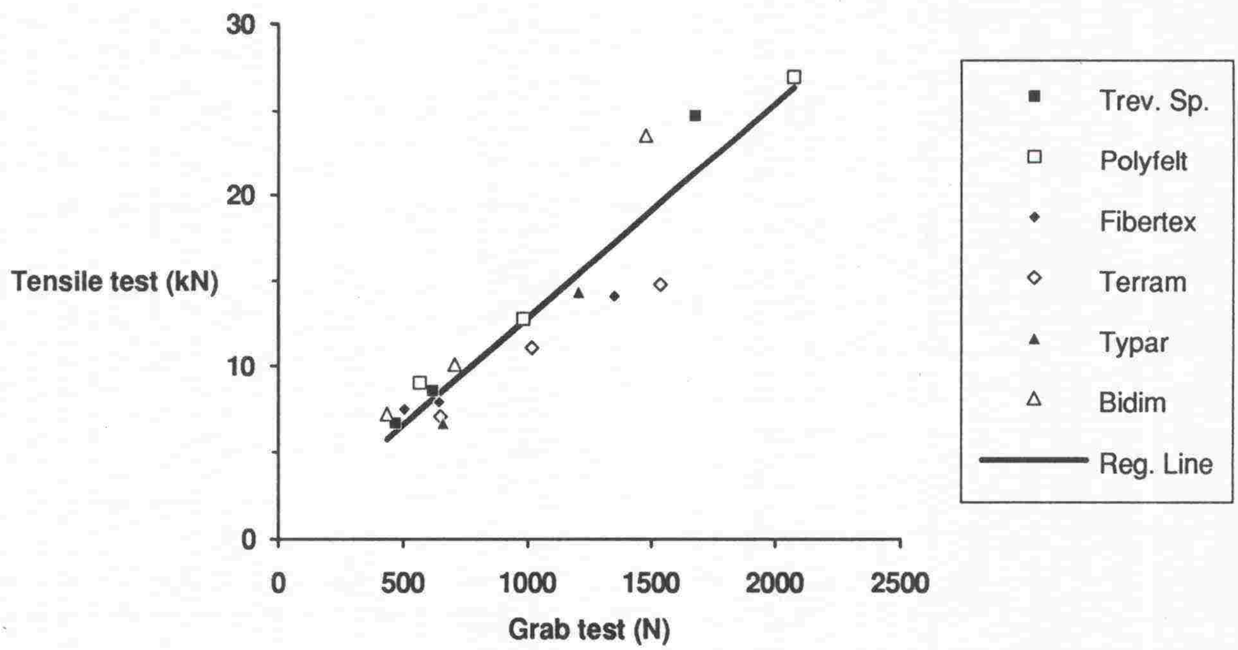


Fig.4.18 Wide width Tensile test (ISO 10 319) and modified Grab test (ASTAM D 4632-86). Comparison of tensile strength values. a) Cross direction b) Machine direction

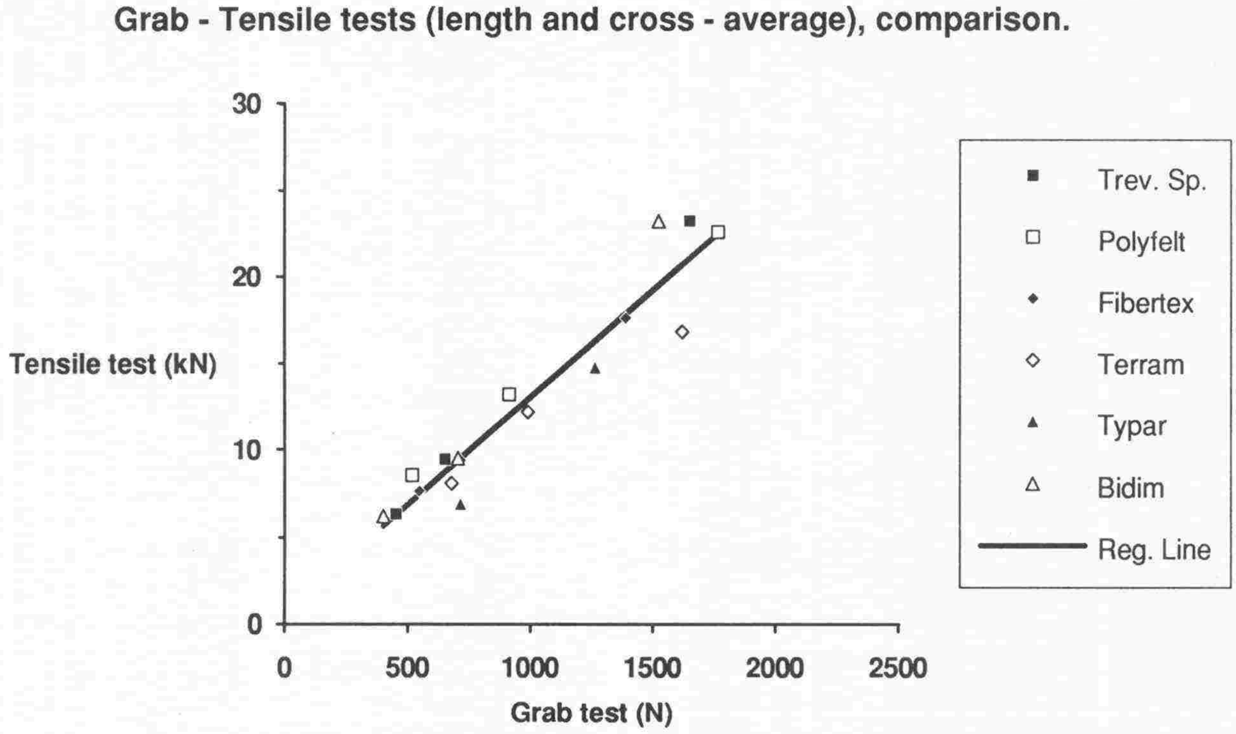
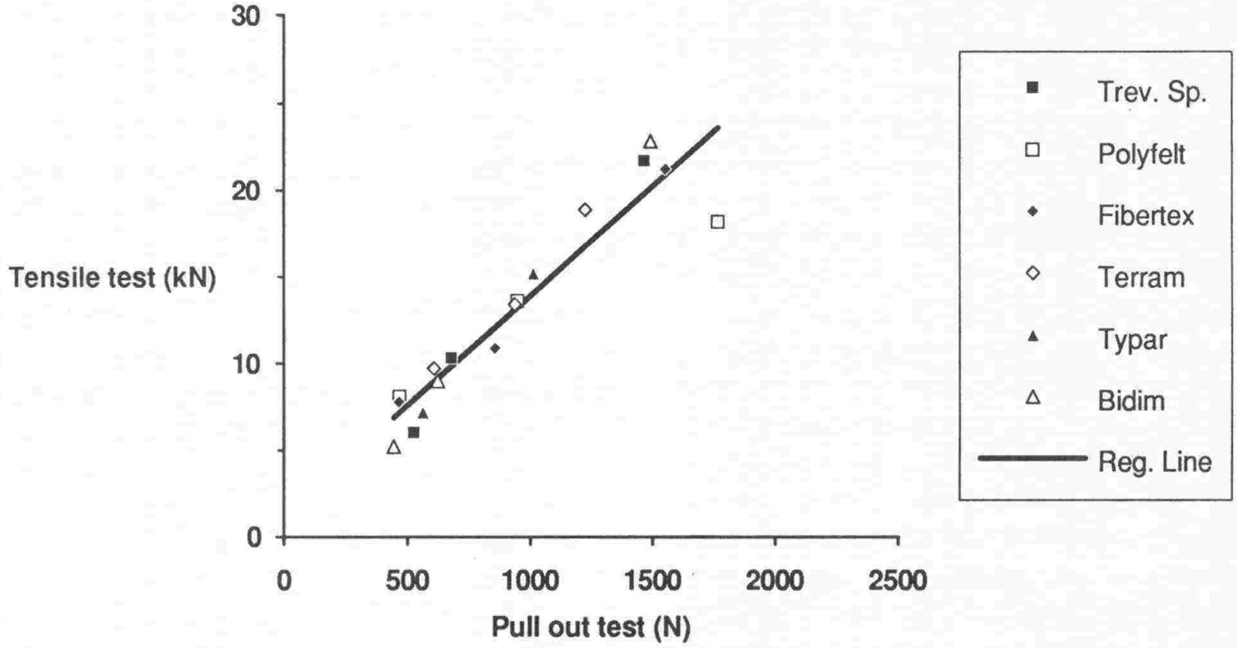


Fig.4.19 Wide width tensile test (ISO 10 319) and modified grab test (ASTAM D 4632-86). Average of cross and machine direction.

a)



b)

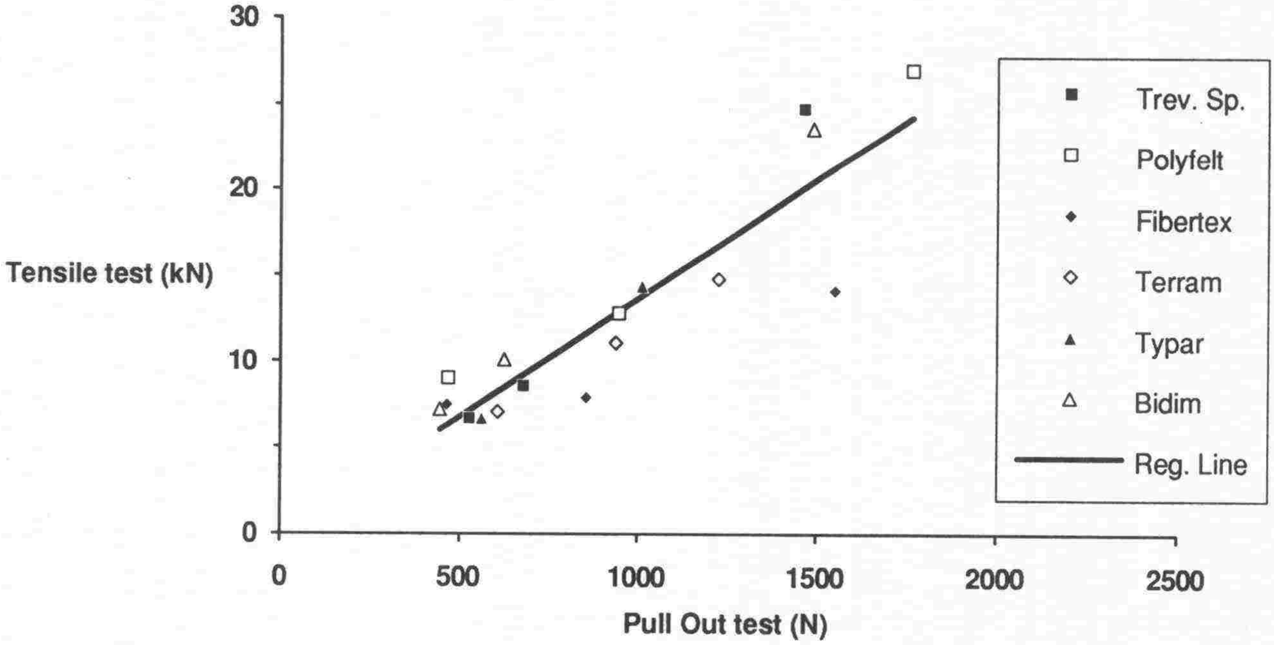


Fig.4.20 Wide width Tensile test (ISO 10 319) and Pull - Out test (NT BUILD 242).
Comparison of maximum strength values. a) Cross direction b) Machine direction

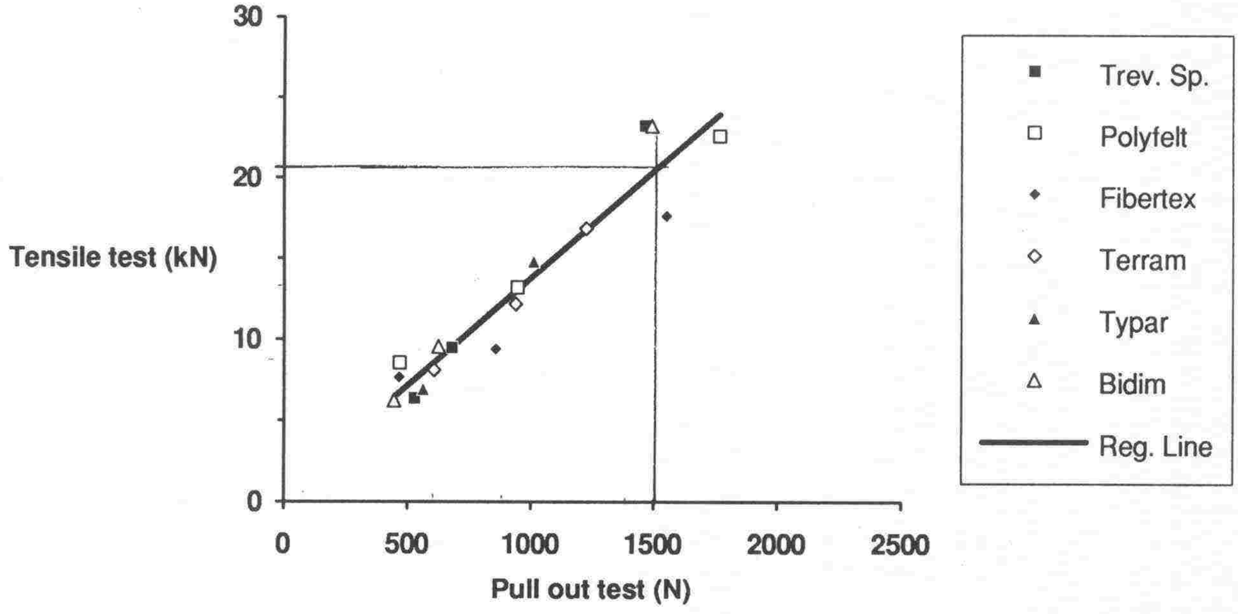


Fig.4.21 Wide width Tensile test (ISO 10 319) and pull-out test (NT BUILD 242). Comparison of maximum strength values. Average of cross and machine direction.

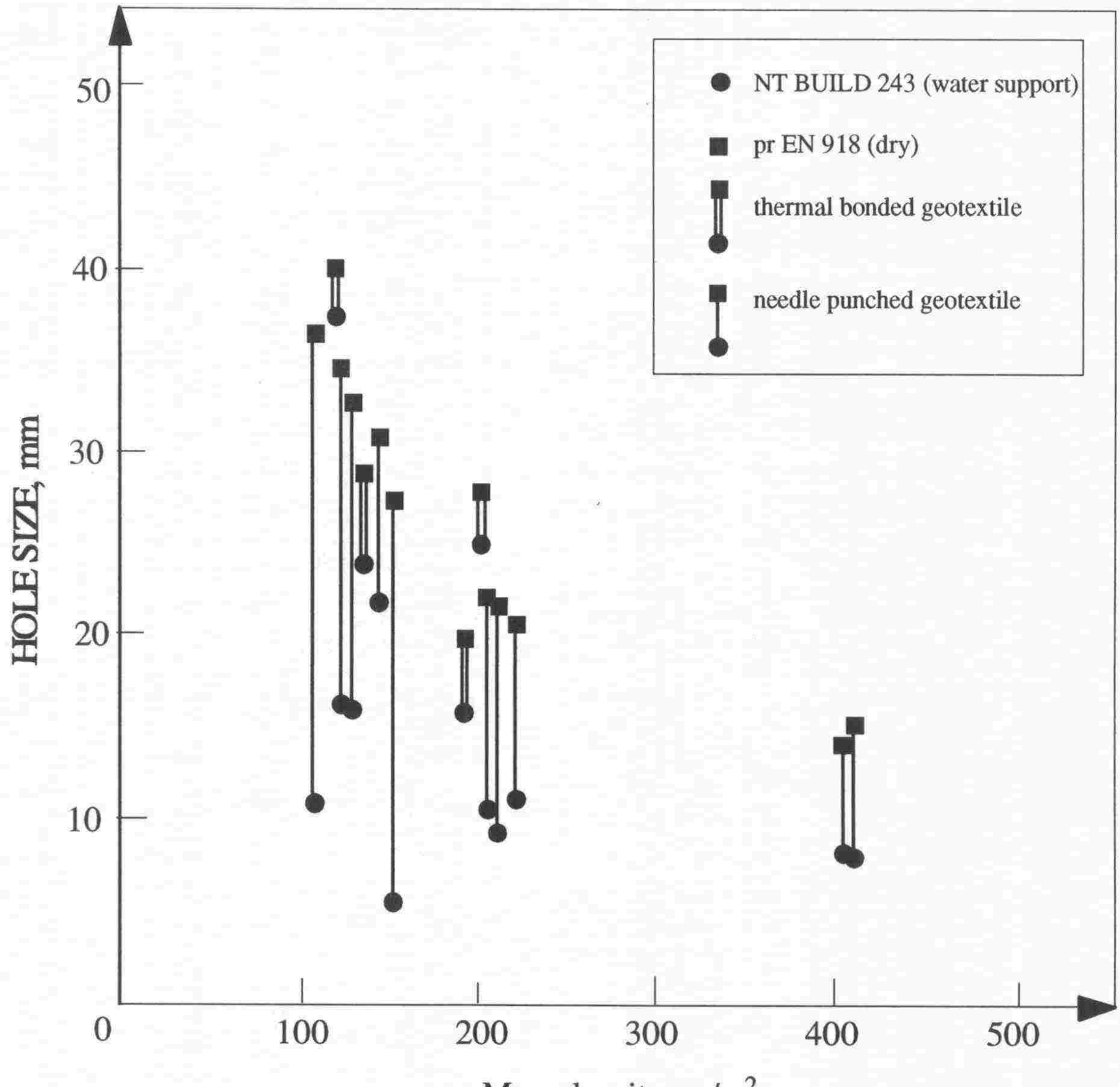


Fig. 4.22 Dynamic impact tests. Hole sizes according to NT BUILD 243 and prEN 918 procedures.

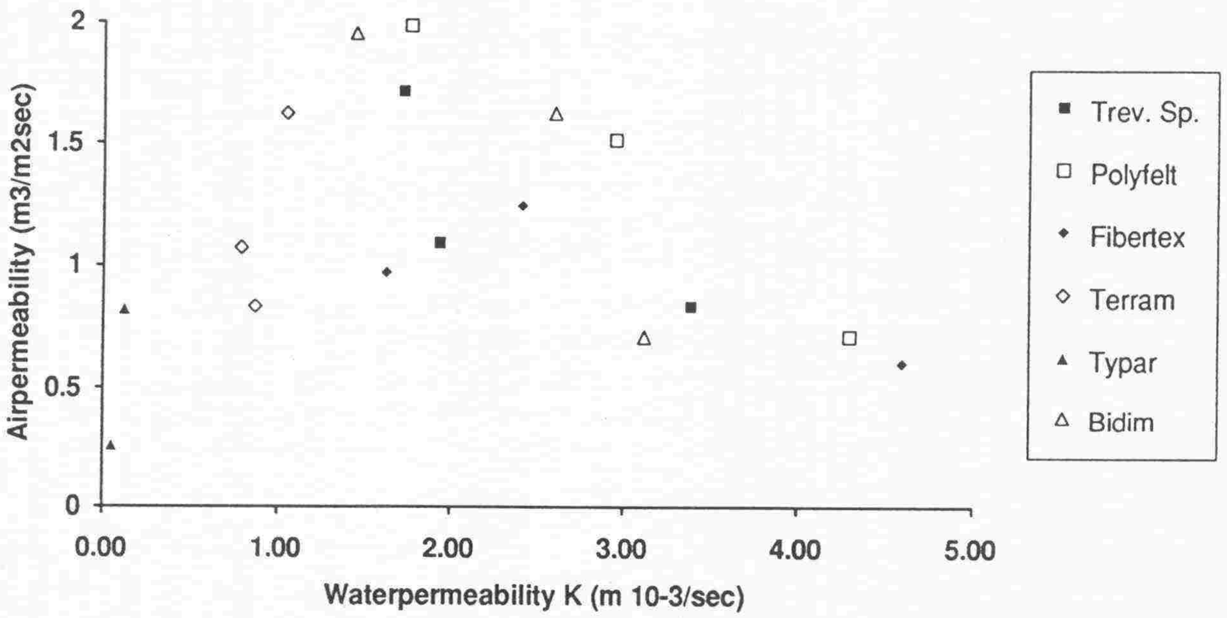


Fig.4.23 Comparison of air and water permeability values of the geotextiles tested.

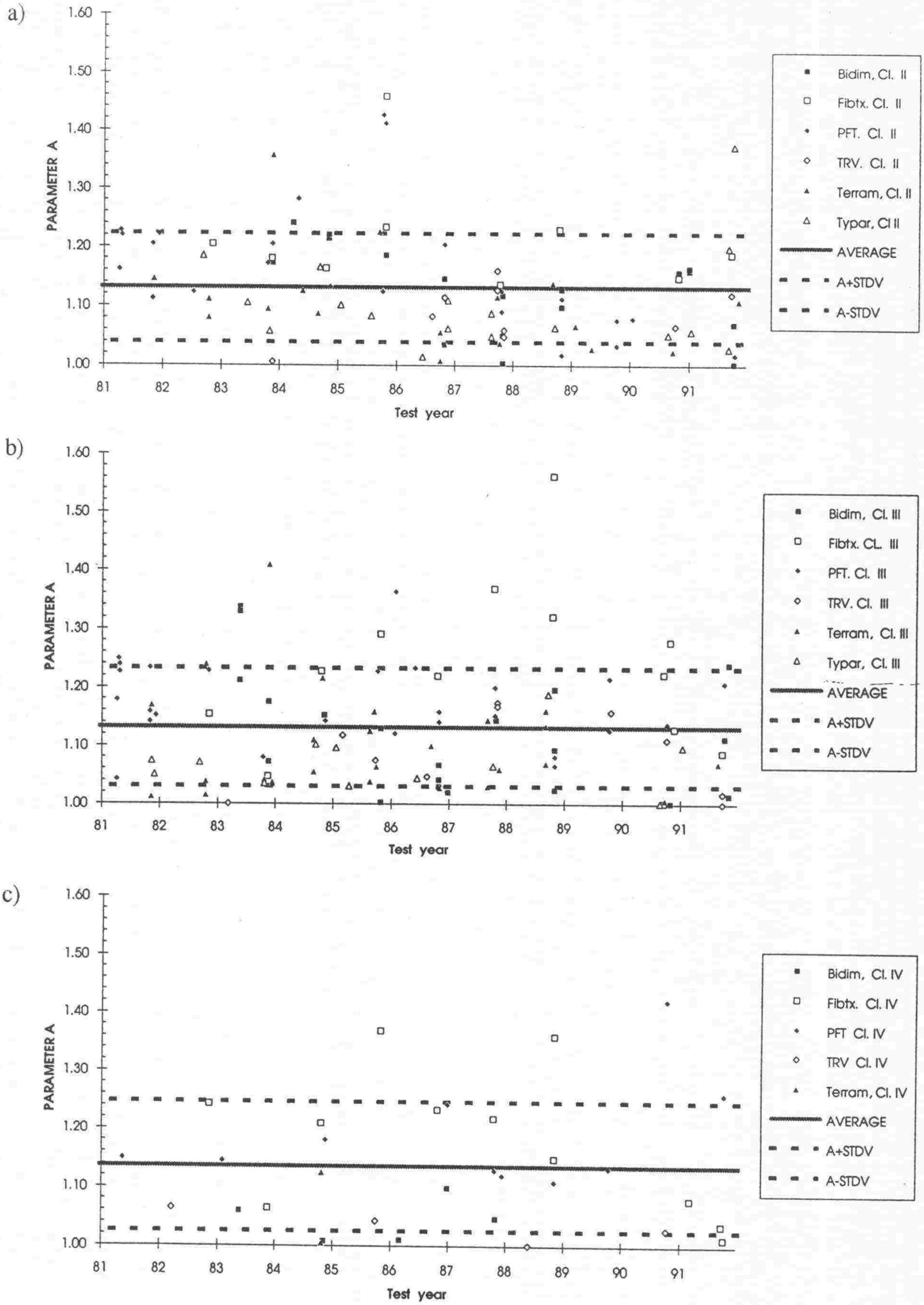


Fig. 5.1 Compilation of test results since 1981 Grab test (ASTM D 4632-86, mod.).
Strength ratio A.
a) in class II b) in class III c) in class IV

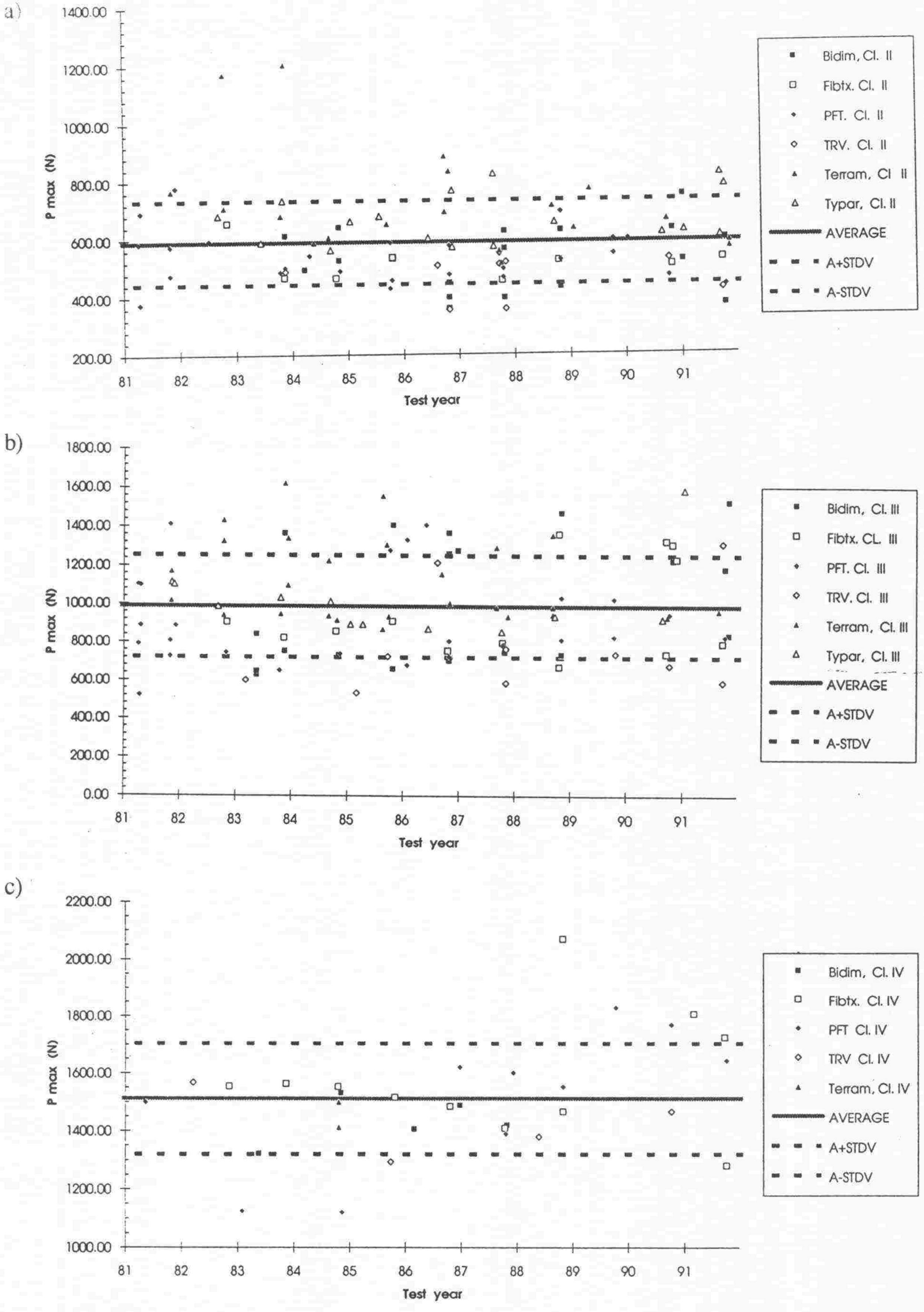
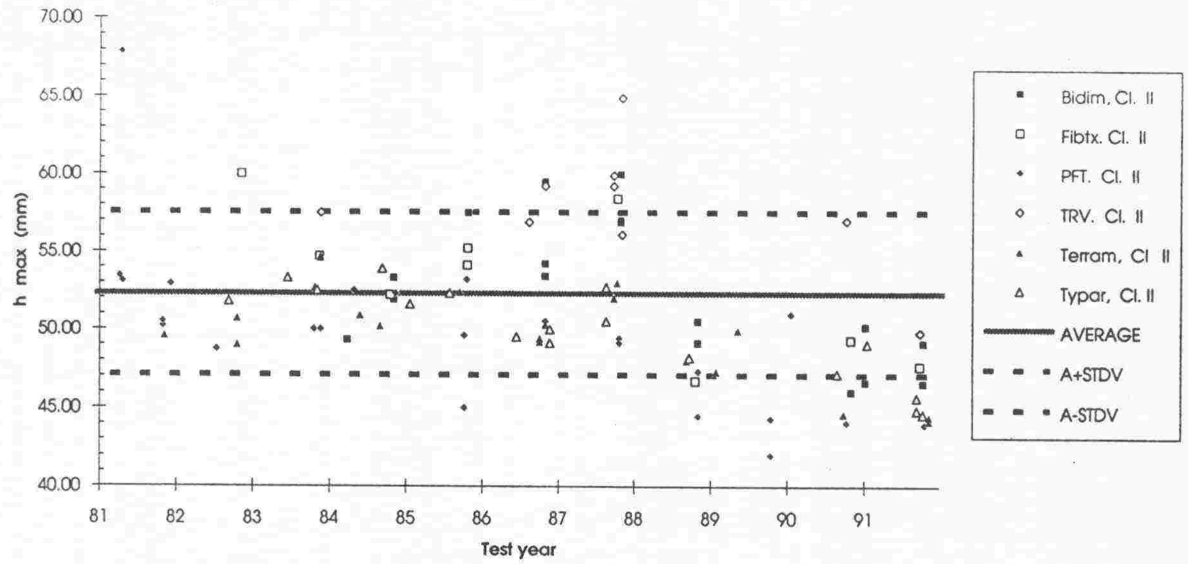
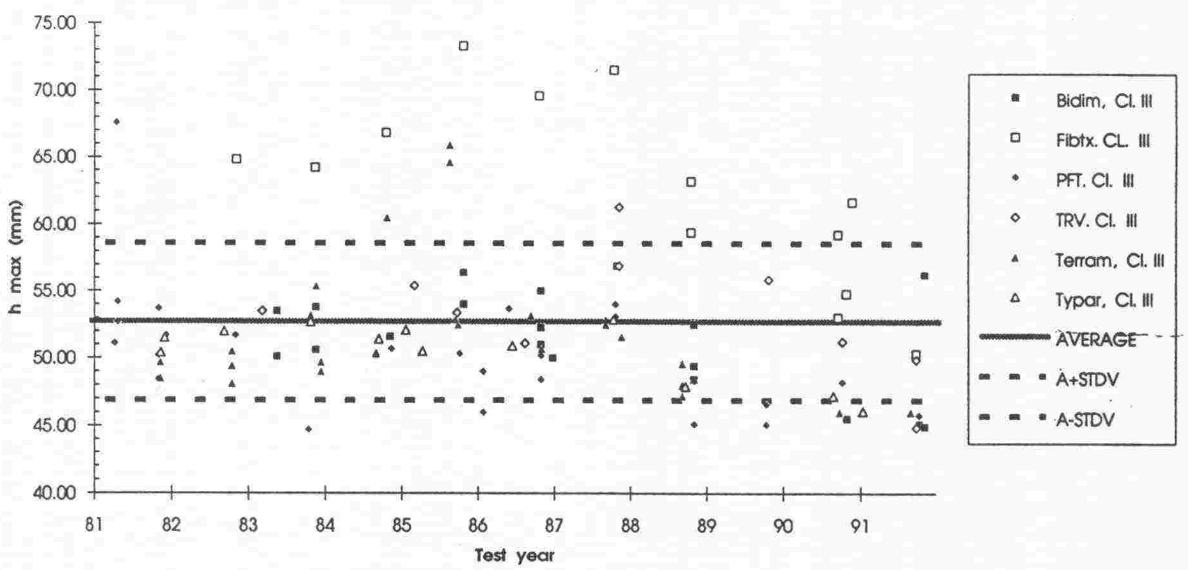


Fig. 5.2 Compilation of test results since 1981. Cone pull out test (NT BUILD 242)
Variation of max. strength. a) in class II b) in class III c) in class IV

a)



b)



c)

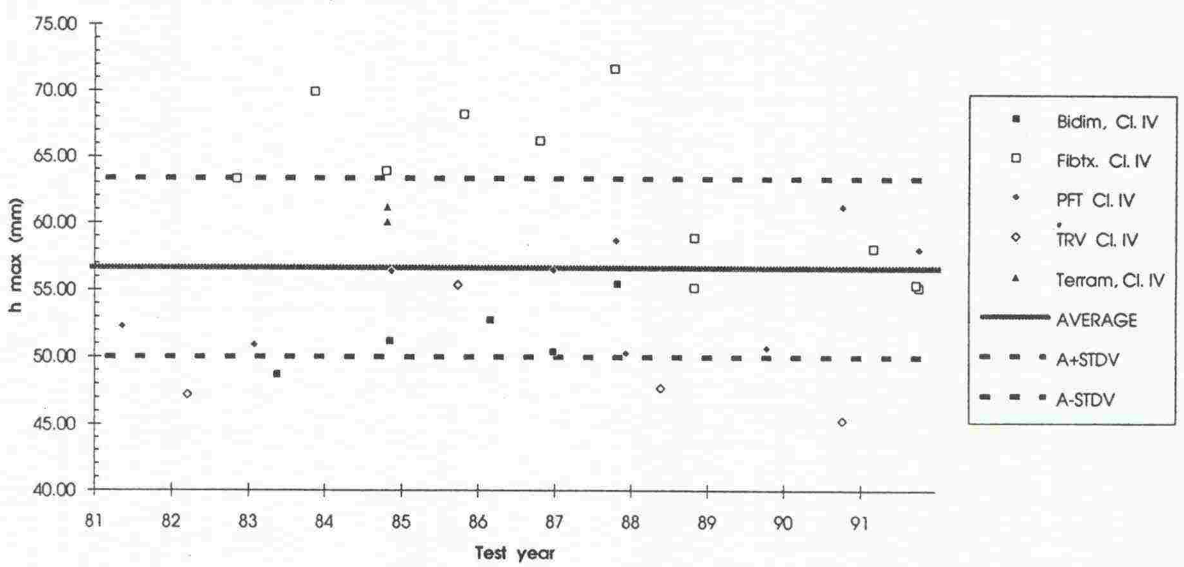
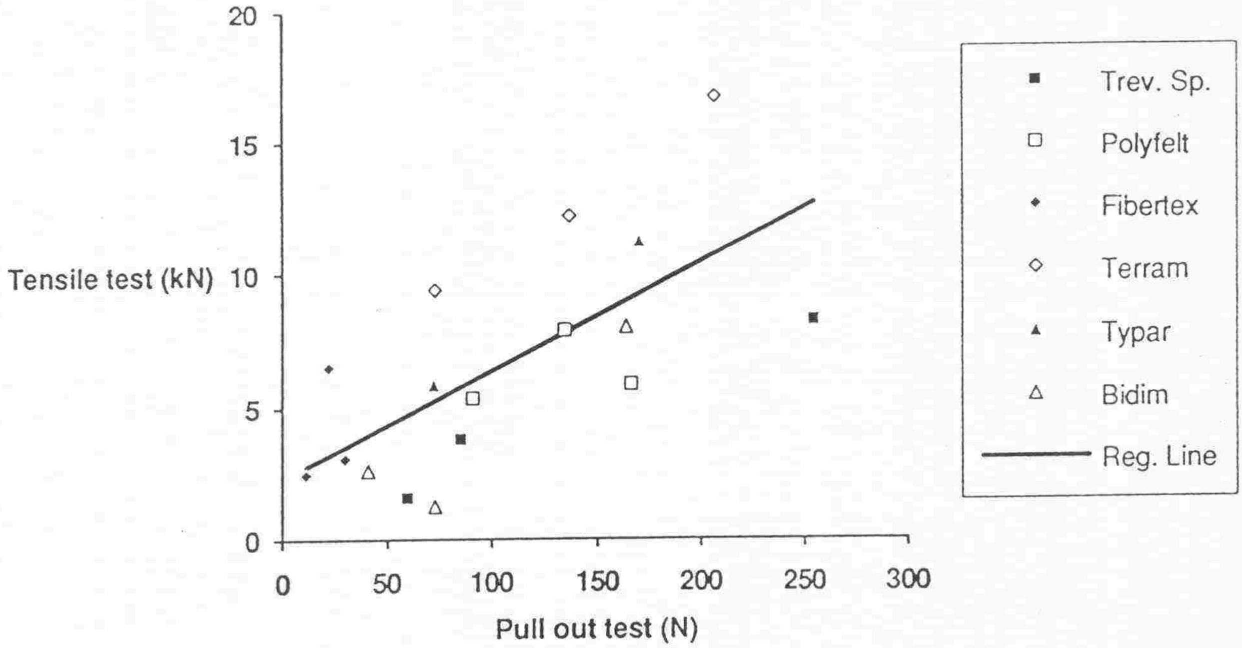


Fig. 5.3 Compilation of test results since 1981. Cone pull out test (NT BUILD 242)
Variation of cone penetration at max. strength.
a) in class II b) in class III c) in class IV

a)



b)

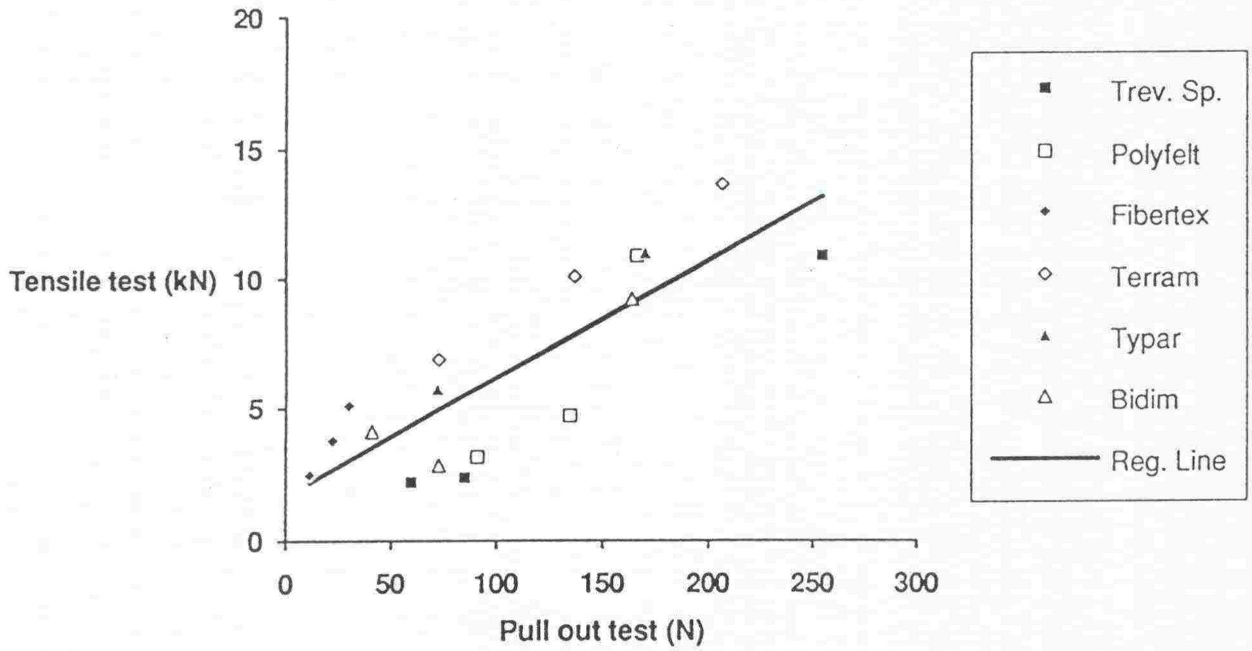
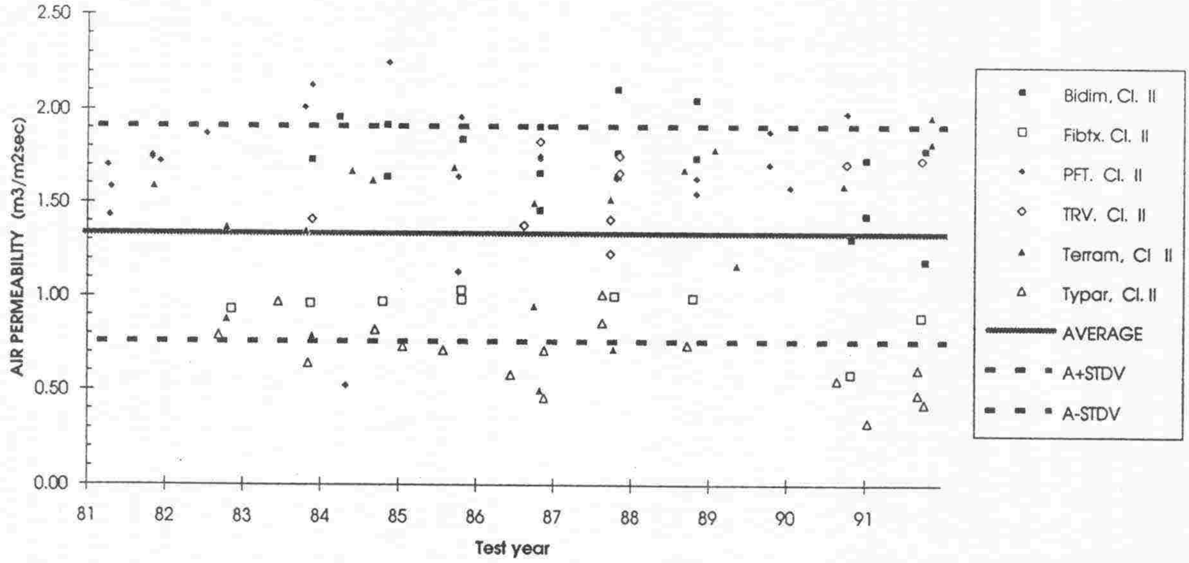
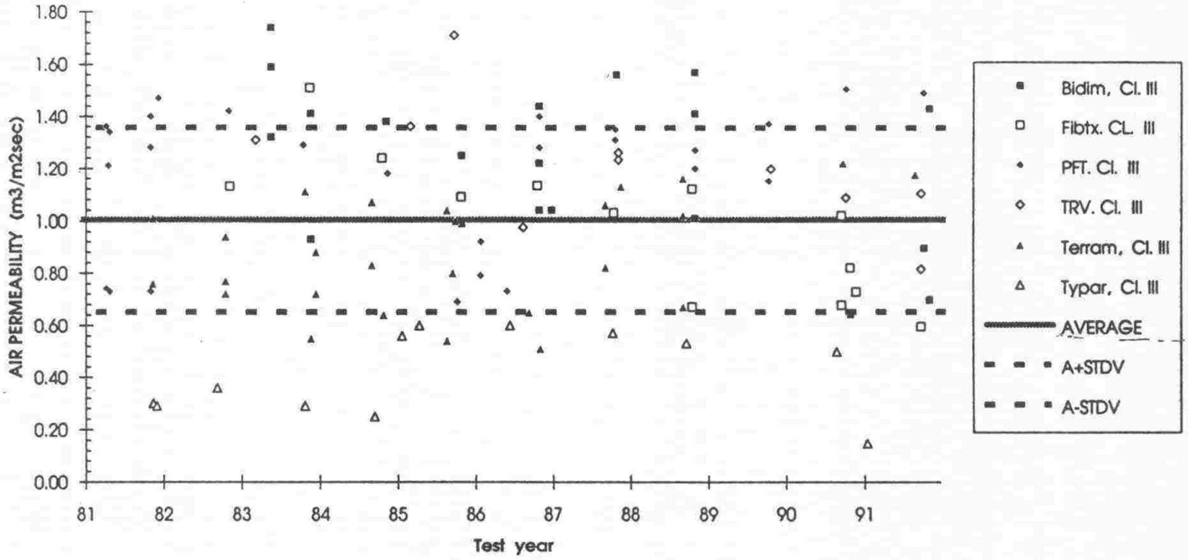


Fig. 5.4 Wide width tensile test (ISO 10 319) and cone pull out test (NT BUILD 242). Comparison of tensile strength at 20 mm deformation. a) Cross direction. b) Machine direction.

a)



b)



c)

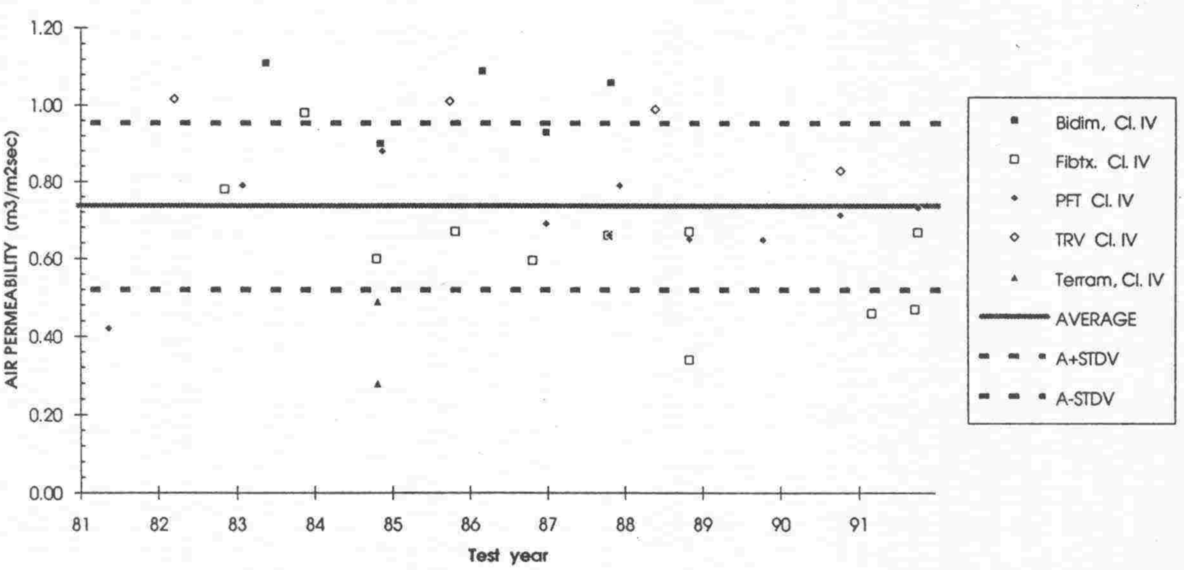
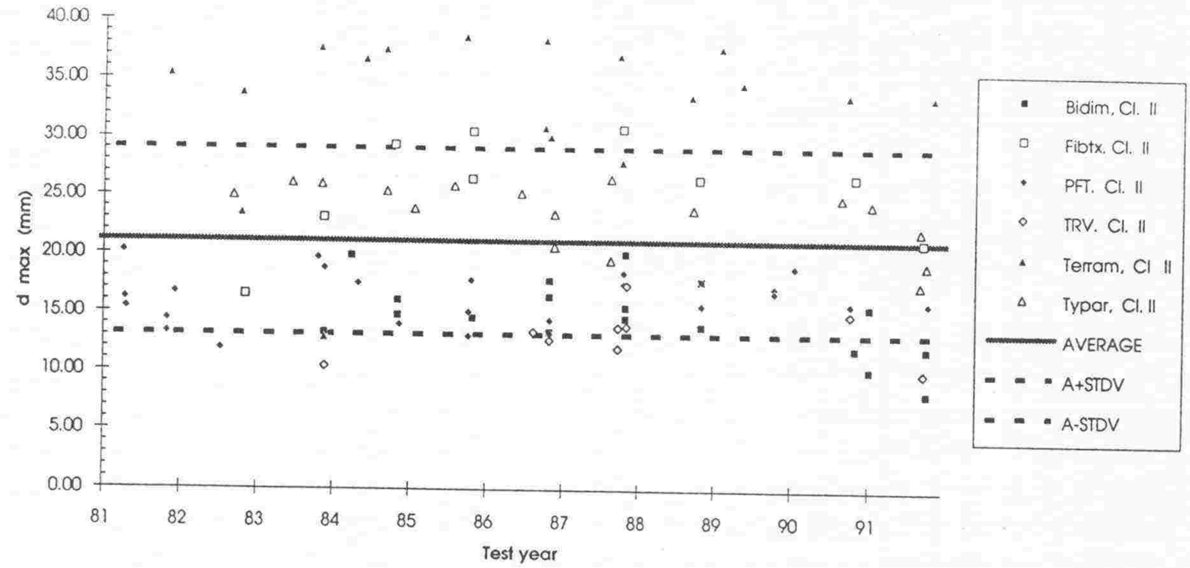
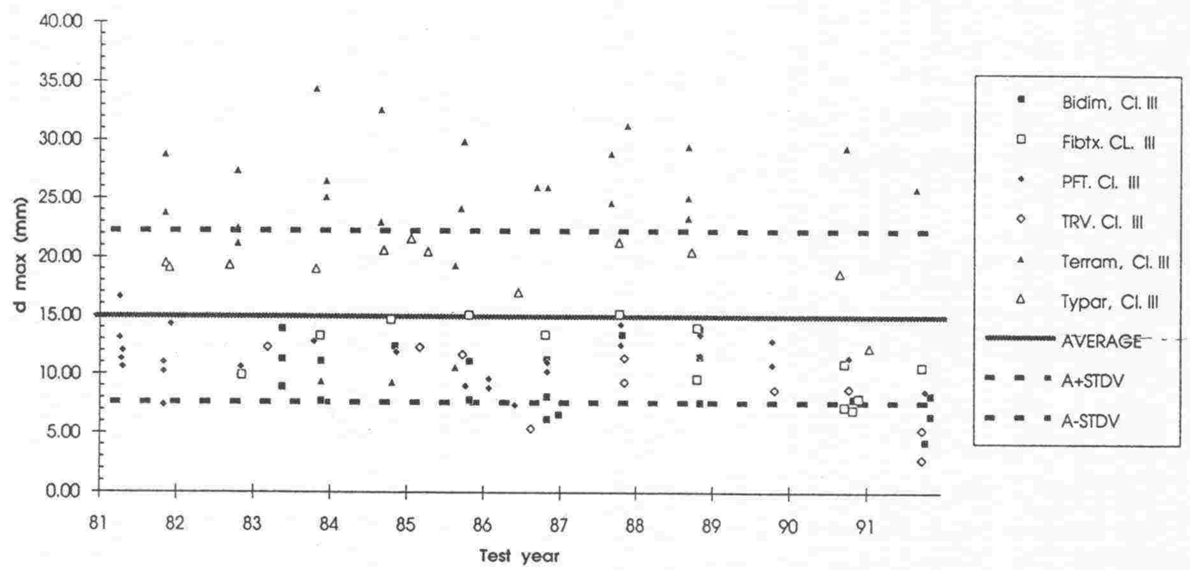


Fig.5.5 Compilation of test results since 1981. Air permeability test (DIN 53887). Variation of air permeability.
a) in class II b) in class III c) in class IV

a)



b)



c)

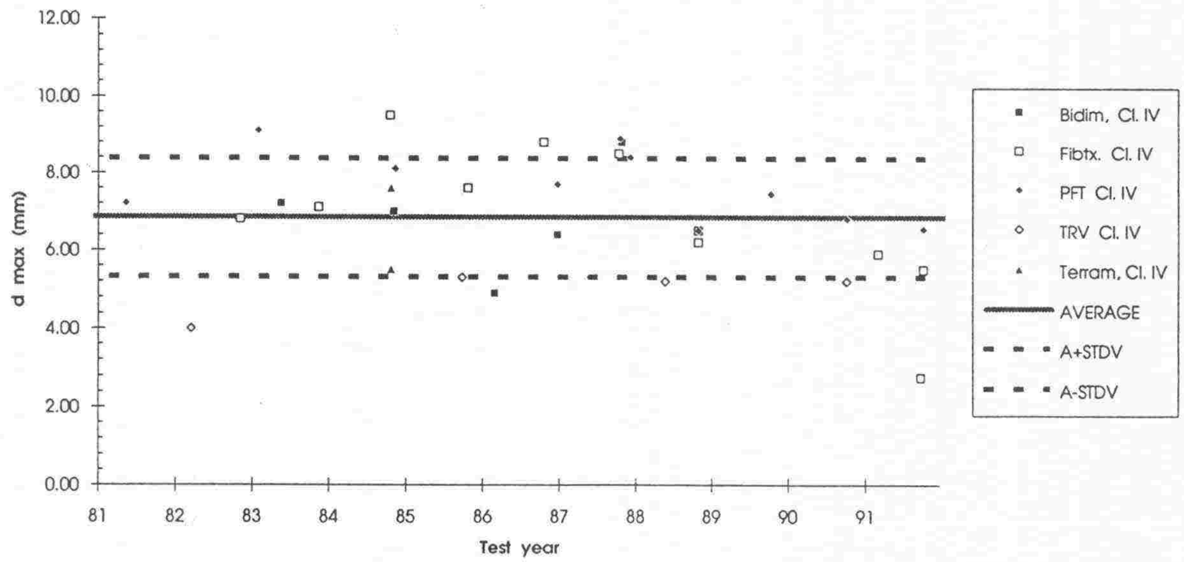


Fig.5.6 Compilation of test results since 1981. Drop cone test (NT BUILD 243). Variation of hole size.
a) in class II b) in class III c) in class IV

VTT-GEOTEXTILE SPECIFICATION, CLASS II

Tensile test results of different geotextile types at 200 mm width samples

HORIZONTAL = CROSS DIRECTION

Geotextile type		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average	Stdv.
Bidim	P_{max} kN/m	5.52	5.42	5.71	5.53	5.17	5.38	5.06	5.13	4.05			5.22	0.46
B-1	P_{20mm} kN/m	1.27	1.47	1.40	1.30	1.12	1.25	1.21	1.14	1.00			1.24	0.14
6139hor.	$P_{max}-P_{20mm}$ kN/m	4.25	3.95	4.31	4.23	4.05	4.13	3.85	3.99	3.05			3.98	0.36
	e_{max} %	83.82	77.00	84.32	80.17	79.04	80.44	81.60	82.33	72.03			80.08	3.57
Fibertex	P_{max} kN/m	6.80	9.56	8.72	7.43	7.88	6.74	6.42	9.20	7.47			7.80	1.06
F-2B	P_{20mm} kN/m	2.90	3.68	3.36	2.85	3.24	2.70	2.63	3.31	3.03			3.08	0.32
3151hor.	$P_{max}-P_{20mm}$ kN/m	3.90	5.88	5.35	4.58	4.63	4.04	3.78	5.89	4.44			4.72	0.76
	e_{max} %	53.26	59.22	60.78	57.43	59.08	56.64	51.73	59.86	54.28			56.92	3.00
Polyfelt	P_{max} kN/m	7.91	8.18	8.05	8.59	8.85	7.58	8.02	8.00	7.63			8.09	0.39
22-ST	P_{20mm} kN/m	5.26	5.60	5.64	4.22	5.54	5.11	5.38	5.14	5.31			5.24	0.40
6516hor.	$P_{max}-P_{20mm}$ kN/m	2.65	2.59	2.41	4.36	3.31	2.47	2.64	2.86	2.32			2.84	0.60
	e_{max} %	37.30	38.13	37.38	41.21	40.87	38.30	35.66	41.94	35.68			38.50	2.20
Trevira S.	P_{max} kN/m	5.02	5.84	6.63	6.39	6.12	6.78	5.97	5.28				6.00	0.58
110	P_{20mm} kN/m	1.25	1.71	1.62	1.67	1.81	1.73	1.44	1.33				1.57	0.19
6500hor.	$P_{max}-P_{20mm}$ kN/m	3.76	4.13	5.01	4.71	4.31	5.04	4.53	3.95				4.43	0.45
	e_{max} %	83.38	83.51	89.80	88.06	83.44	88.76	90.26	83.38				86.33	2.96
Terram	P_{max} kN/m	10.88	8.35	8.67	9.25	10.05	11.33	10.36	9.22	9.17			9.70	0.95
1000	P_{20mm} kN/m	10.45	8.23	8.51	9.14	9.56	10.66	9.83	9.05	8.88			9.37	0.78
3154hor.	$P_{max}-P_{20mm}$ kN/m	0.43	0.12	0.16	0.11	0.48	0.67	0.52	0.17	0.29			0.33	0.19
	e_{max} %	24.43	22.30	22.52	21.31	24.05	24.81	23.67	22.17	22.91			23.13	1.11
Typar	P_{max} kN/m	7.65	6.47	8.02	7.26	6.74	7.08	6.89	7.81	7.02	6.70		7.16	0.49
136	P_{20mm} kN/m	6.29	5.40	6.26	5.83	6.00	5.64	5.46	6.54	5.93	5.52		5.89	0.37
3164hor.	$P_{max}-P_{20mm}$ kN/m	1.36	1.07	1.75	1.43	0.74	1.44	1.42	1.27	1.08	1.18		1.27	0.26
	e_{max} %	52.10	52.96	59.32	61.99	43.16	57.83	56.12	42.99	42.45	48.31		51.72	6.84

Tab. 4.2a Wide width tensile test (ISO 10 319). VTT-GEO class II products. Cross direction

VTT-GEOTEXTILE SPECIFICATION, CLASS II

Tensile test results of different geotextile types at 200 mm width samples

VERTICAL = LENGTH DIRECTION

Geotextile type		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average	Stdv.
Bidim B-1 6139vert.	P_{max} kN/m	7.33	6.72	8.17	5.53	7.50	6.84	6.82	7.72	7.77	7.27		7.17	0.70
	P_{20mm} kN/m	2.98	2.73	3.21	2.49	2.73	2.67	2.63	3.03	3.34	2.66		2.85	0.26
	$P_{max}-P_{20mm}$ kN/m	4.35	3.99	4.95	3.04	4.77	4.17	4.18	4.69	4.43	4.61		4.32	0.51
	e_{max} %	70.65	66.67	71.27	58.39	76.13	67.78	71.61	70.94	63.84	76.02		69.33	5.13
Fibertex F-2B 3151vert.	P_{max} kN/m	8.18	7.85	7.41	8.45	7.95	7.26	7.90	6.81	5.24	8.11	6.92	7.46	0.86
	P_{20mm} kN/m	5.46	5.55	5.04	5.34	5.29	4.87	5.46	4.45	3.98	5.51	5.01	5.09	0.47
	$P_{max}-P_{20mm}$ kN/m	2.71	2.30	2.37	3.11	2.66	2.38	2.44	2.36	1.25	2.60	1.91	2.37	0.45
	e_{max} %	42.02	38.32	40.26	42.52	39.84	38.50	38.59	46.59	33.26	39.45	35.42	39.52	3.37
Polyfelt 22-ST 6516vert.	P_{max} kN/m	8.96	9.07	9.34	10.00	8.57	8.47	9.14	9.03	8.12	9.47	8.75	8.99	0.49
	P_{20mm} kN/m	2.99	3.20	3.30	3.55	2.84	2.77	3.23	3.27	2.95	3.38	3.01	3.14	0.23
	$P_{max}-P_{20mm}$ kN/m	5.97	5.87	6.04	6.45	5.73	5.70	5.91	5.76	5.17	6.09	5.74	5.86	0.30
	e_{max} %	98.64	88.00	89.44	87.02	93.72	93.14	95.08	87.90	84.23	91.90	93.78	91.17	4.02
Trevira S. 110 6500vert.	P_{max} kN/m	6.54	6.00	5.36	7.43	6.66	5.90	8.20	7.59	5.92	6.86		6.64	0.84
	P_{20mm} kN/m	1.98	1.92	1.80	2.49	2.18	2.03	2.72	2.20	2.05	2.41		2.18	0.27
	$P_{max}-P_{20mm}$ kN/m	4.56	4.07	3.55	4.94	4.47	3.86	5.48	5.39	3.87	4.45		4.47	0.62
	e_{max} %	84.18	78.46	70.09	74.00	83.32	72.94	75.55	84.24	74.60	75.57		77.29	4.78
Terram 1000 3154vert.	P_{max} kN/m	7.16	6.39	7.25	7.21	7.05	6.57	7.66	6.77	7.12	6.97		7.01	0.34
	P_{20mm} kN/m	7.14	6.38	6.99	7.15	6.97	6.28	7.50	6.73	6.99	6.79		6.89	0.35
	$P_{max}-P_{20mm}$ kN/m	0.01	0.01	0.26	0.06	0.08	0.29	0.15	0.04	0.13	0.17		0.12	0.09
	e_{max} %	20.38	21.08	24.52	21.08	21.36	17.25	22.21	21.22	22.39	22.89		21.44	1.79
Typar 136 3164vert.	P_{max} kN/m	6.73	6.98	6.70	6.00	7.54	6.31	7.31	7.01	6.36	5.57		6.65	0.57
	P_{20mm} kN/m	5.67	6.04	5.62	5.40	6.38	5.74	5.91	6.15	5.44	5.22		5.76	0.35
	$P_{max}-P_{20mm}$ kN/m	1.05	0.94	1.08	0.60	1.16	0.56	1.40	0.85	0.92	0.35		0.89	0.30
	e_{max} %	54.44	43.32	67.29	54.24	53.77	45.20	73.97	42.39	57.22	35.14		52.70	11.19

Tab. 4.2b Wide width tensile test (ISO 10 319). VTT-GEO class II products. Machine direction

VTT-GEOTEXTILE SPECIFICATION, CLASS III

Tensile test results of different geotextile types at 200 mm width samples

HORIZONTAL = CROSS DIRECTION

Geotextile type		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average	Stdv.
Bidim	P_{max} kN/m	8.62	7.42	7.58	9.39	10.03	9.98	8.58	8.56	10.02	9.80		9.00	0.94
B-3	P_{20mm} kN/m	2.56	2.35	2.11	2.73	2.87	2.96	2.51	2.54	2.89	2.89		2.64	0.26
5408hor.	$P_{max}-P_{20mm}$ kN/m	6.06	5.07	5.46	6.65	7.16	7.01	6.07	6.02	7.12	6.90		6.35	0.69
	e_{max} %	76.28	71.82	76.44	78.80	84.86	76.87	77.96	77.71	83.69	75.97		78.04	3.59
Fibertex	P_{max} kN/m	10.29	9.29	11.29	10.36	11.80	10.18	11.54	11.66	10.98	11.61		10.90	0.79
F-32M	P_{20mm} kN/m	2.28	1.96	2.64	2.38	2.65	2.12	2.50	2.46	2.77	3.05		2.48	0.30
3162hor..	$P_{max}-P_{20mm}$ kN/m	8.00	7.32	8.65	7.98	9.15	8.06	9.04	9.20	8.21	8.55		8.42	0.58
	e_{max} %	69.57	66.19	75.20	73.42	70.05	70.02	67.38	70.40	64.01	63.35		68.96	3.60
Polyfelt	P_{max} kN/m	13.50	13.53	12.42	11.92	13.06	15.08	15.54	13.51	14.43	12.96		13.59	1.08
TS-500 (TS-21)	P_{20mm} kN/m	8.15	8.06	7.67	4.05	8.27	8.54	9.27	8.25	8.92	8.09		7.93	1.36
6517hor..	$P_{max}-P_{20mm}$ kN/m	5.35	5.46	4.75	7.86	4.79	6.54	6.28	5.25	5.50	4.87		5.66	0.92
	e_{max} %	47.10	47.23	43.77	91.24	41.96	50.31	48.36	44.13	45.66	42.63		50.24	13.89
Trevira S.	P_{max} kN/m	9.23	9.99	8.87	10.28	11.41	10.49	10.96	10.30	11.84	9.76		10.31	0.88
150	P_{20mm} kN/m	3.12	3.77	3.15	4.02	4.33	3.75	4.29	3.97	4.33	3.48		3.82	0.43
6501hor..	$P_{max}-P_{20mm}$ kN/m	6.11	6.22	5.72	6.26	7.08	6.74	6.67	6.33	7.51	6.28		6.49	0.49
	e_{max} %	71.99	68.35	69.53	66.82	68.22	71.44	66.17	68.70	70.63	66.73		68.86	1.91
Terram	P_{max} kN/m	14.11	12.67	12.97	15.19	14.75	16.26	13.09	13.43	9.66	11.87		13.40	1.76
1500	P_{20mm} kN/m	12.71	11.45	12.08	13.47	13.46	14.31	12.17	12.42	9.03	10.75		12.19	1.44
3155hor..	$P_{max}-P_{20mm}$ kN/m	1.40	1.22	0.88	1.72	1.29	1.94	0.92	1.01	0.62	1.12		1.21	0.38
	e_{max} %	29.45	28.62	27.04	29.83	27.77	30.24	26.16	26.23	27.67	28.23		28.12	1.35
Typar	P_{max} kN/m	13.14	16.02	16.25	16.22	14.49	15.86	15.25	13.14	15.21	16.28		15.18	1.16
230	P_{20mm} kN/m	9.78	11.73	11.75	11.93	11.00	11.61	11.32	10.16	11.18	11.70		11.22	0.68
3165hor..	$P_{max}-P_{20mm}$ kN/m	3.35	4.29	4.50	4.29	3.49	4.24	3.93	2.97	4.02	4.58		3.97	0.50
	e_{max} %	72.16	66.06	80.16	79.06	54.07	71.15	65.55	64.32	65.91	69.90		68.84	7.18

Tab. 4.3a Wide width tensile test (ISO 10 319). VTT-GEO class III products. Cross direction

VTT-GEOTEXTILE SPECIFICATION, CLASS III

Tensile test results of different geotextile types at 200 mm width samples

VERTICAL = LENGTH DIRECTION

Geotextile type		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average	Stdv.
Bidim	P_{max} kN/m	8.85	9.00	11.11	10.16	9.61	9.52	10.95	10.81	10.77	10.29		10.10	0.78
B-3	P_{20mm} kN/m	3.58	3.86	4.72	4.09	3.72	3.93	4.47	4.46	4.41	4.19		4.14	0.35
5408vert	$P_{max}-P_{20mm}$ kN/m	5.27	5.14	6.39	6.06	5.89	5.59	6.48	6.35	6.36	6.09		5.96	0.46
	e_{max} %	63.65	62.35	67.07	70.98	71.65	65.24	67.87	66.86	68.03	67.72		67.14	2.75
Fibertex	P_{max} kN/m	7.09	7.61	7.66	7.28	8.60	8.66	7.82	7.50	8.51	7.87		7.86	0.53
F-32M	P_{20mm} kN/m	2.28	1.97	2.60	2.25	2.85	2.66	2.33	2.52	2.59	2.38		2.44	0.24
3162vert.	$P_{max}-P_{20mm}$ kN/m	4.81	5.64	5.06	5.03	5.74	6.00	5.48	4.98	5.92	5.49		5.42	0.40
	e_{max} %	61.40	63.08	63.75	64.14	67.16	70.10	67.02	68.61	63.53	63.47		65.23	2.66
Polyfelt	P_{max} kN/m	12.52	13.72	12.90	12.35	14.22	10.53	11.88	14.16				12.78	1.17
TS-500 (TS-21)	P_{20mm} kN/m	4.38	4.52	4.26	3.87	4.89	3.52	3.94	8.28				4.71	1.41
6517vert.	$P_{max}-P_{20mm}$ kN/m	8.14	9.20	8.64	8.48	9.33	7.01	7.94	5.88				8.08	1.08
	e_{max} %	86.04	99.16	96.52	98.52	92.38	85.36	95.00	48.77				87.72	15.51
Trevira S.	P_{max} kN/m	10.19	8.17	8.54	7.60	8.84	8.55	8.73	9.12	7.79	8.13		8.56	0.70
150	P_{20mm} kN/m	2.94	2.37	1.92	2.22	2.23	2.18	2.54	2.70	2.27	2.42		2.38	0.28
6501vert.	$P_{max}-P_{20mm}$ kN/m	7.25	5.80	6.62	5.38	6.61	6.36	6.18	6.42	5.52	5.71		6.18	0.55
	e_{max} %	74.25	73.07	78.54	69.66	80.74	80.98	76.43	70.28	72.89	76.44		75.33	3.79
Terram	P_{max} kN/m	13.39	8.89	12.10	8.85	10.40	10.18	11.37	12.60	11.32	11.71		11.08	1.42
1500	P_{20mm} kN/m	12.31	8.45	10.81	8.05	9.60	9.34	10.31	11.26	10.42	10.22		10.08	1.21
3155vert.	$P_{max}-P_{20mm}$ kN/m	1.08	0.44	1.28	0.80	0.80	0.84	1.06	1.34	0.89	1.49		1.00	0.30
	e_{max} %	27.05	24.77	28.56	27.69	26.93	27.82	28.45	28.56	26.90	31.44		27.82	1.62
Typar	P_{max} kN/m	15.11	14.25	14.60	14.82	13.46	14.58	14.27	14.62	13.98	14.05		14.37	0.45
230	P_{20mm} kN/m	11.14	11.00	11.70	11.08	10.23	11.21	10.55	11.56	10.70	11.00		11.02	0.42
3165vert.	$P_{max}-P_{20mm}$ kN/m	3.97	3.24	2.90	3.74	3.23	3.37	3.72	3.06	3.28	3.05		3.35	0.33
	e_{max} %	77.99	58.73	51.78	78.78	79.24	79.46	78.87	50.21	60.87	62.44		67.84	11.57

Tab. 4.3b Wide width tensile test (ISO 10 319). VTT-GEO class III products. Machine direction

VTT-GEOTEXTILE SPECIFICATION, CLASS IV

Tensile test results of different geotextile types at 200 mm width samples

HORIZONTAL = CROSS DIRECTION

Geotextile type		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average	Stdv.
Bidim	P_{max} kN/m	22.26	22.58	20.85	22.81	23.94	22.11	22.50	22.55	24.82	23.94		22.83	1.07
B-7	P_{20mm} kN/m	7.81	8.07	7.58	8.01	8.39	7.60	8.20	8.27	8.35	8.37		8.07	0.29
6143hor.	$P_{max}-P_{20mm}$ kN/m	14.45	14.51	13.27	14.80	15.54	14.51	14.29	14.27	16.47	15.57		14.77	0.84
	e_{max} %	76.30	74.76	71.68	75.62	77.32	77.99	74.87	71.72	81.52	79.26		76.10	2.94
Fibertex	P_{max} kN/m	20.15	22.71	20.16	21.60	22.49	22.96	22.23	19.96	19.26	20.53		21.20	1.27
F-4M	P_{20mm} kN/m	6.43	7.21	6.47	7.51	6.76	5.35	7.15	5.70	6.32	6.30		6.52	0.64
3152hor..	$P_{max}-P_{20mm}$ kN/m	13.72	15.49	13.69	14.09	15.73	17.60	15.08	14.26	12.94	14.22		14.68	1.27
	e_{max} %	49.58	54.54	51.07	53.41	54.26	59.22	55.13	56.05	50.84	53.55		53.76	2.67
Polyfelt	P_{max} kN/m	18.24	19.09	18.10	17.74	17.82	19.61	18.44	16.38	17.73	18.29		18.14	0.82
TS-750	P_{20mm} kN/m	6.02	5.99	5.67	5.95	5.84	6.28	5.98	5.62	5.56	6.14		5.91	0.22
6518hor..	$P_{max}-P_{20mm}$ kN/m	12.21	13.10	12.43	11.78	11.98	13.33	12.46	10.76	12.17	12.14		12.24	0.67
	e_{max} %	98.98	99.18	99.08	97.62	99.06	99.04	96.64	94.78	99.20	98.94		98.25	1.41
Trevira S.	P_{max} kN/m	22.16	21.57	20.36	21.82	22.19	21.60	21.26	22.40	20.69	23.03		21.71	0.76
300	P_{20mm} kN/m	7.70	8.03	7.34	7.94	8.69	7.97	7.59	7.98	6.91	8.30		7.84	0.47
6502hor..	$P_{max}-P_{20mm}$ kN/m	14.46	13.54	13.02	13.88	13.50	13.63	13.67	14.42	13.77	14.73		13.86	0.50
	e_{max} %	68.43	66.36	64.62	67.72	65.42	67.04	65.30	70.17	71.75	66.96		67.38	2.13
Terram	P_{max} kN/m	17.93	19.74	17.71	19.47	20.59	19.30	18.98	18.70	16.45	19.61		18.85	1.14
3000	P_{20mm} kN/m	15.76	17.79	16.19	17.96	17.34	17.16	17.05	16.12	14.66	17.53		16.76	0.99
3156hor..	$P_{max}-P_{20mm}$ kN/m	2.17	1.94	1.52	1.51	3.24	2.14	1.93	2.58	1.79	2.08		2.09	0.49
	e_{max} %	30.10	28.78	27.87	27.92	34.96	30.30	28.74	31.82	29.28	29.61		29.94	2.01

Tab. 4.4a Wide width tensile test (ISO 10 319). VTT-GEO class IV products. Cross direction

VTT-GEOTEXTILE SPECIFICATION, CLASS IV

Tensile test results of different geotextile types at 200 mm width samples

VERTICAL = LENGTH DIRECTION

Geotextile type		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average	Stdv.
Bidim	P_{max} kN/m	23.04	23.54	21.73	24.55	23.78	22.61	25.14	27.09	20.45	24.12		23.60	1.75
B-7	P_{20mm} kN/m	9.16	8.94	8.47	9.32	8.77	9.03	9.90	10.34	8.16	10.00		9.21	0.66
6143vert	$P_{max}-P_{20mm}$ kN/m	13.88	14.60	13.26	15.22	15.01	13.58	15.24	16.75	12.28	14.12		14.39	1.19
	e_{max} %	71.51	76.39	71.76	74.82	74.92	70.09	72.44	77.92	68.48	67.80		72.61	3.18
Fibertex	P_{max} kN/m	13.75	11.74	12.97	15.88	16.65	12.55	13.29	13.47	15.08	15.63		14.10	1.53
F-4M	P_{20mm} kN/m	2.97	3.28	3.51	4.27	4.47	3.38	3.97	3.50	3.81	4.25		3.74	0.47
3152vert.	$P_{max}-P_{20mm}$ kN/m	10.78	8.46	9.46	11.61	12.18	9.17	9.32	9.97	11.27	11.37		10.36	1.18
	e_{max} %	75.88	61.07	67.39	72.43	68.63	65.29	64.21	65.79	67.28	66.50		67.45	3.96
Polyfelt	P_{max} kN/m	28.47	25.45	26.94	26.16	26.00	26.19	27.23	27.62	28.69			26.97	1.07
TS-750	P_{20mm} kN/m	10.98	11.07	11.19	10.69	10.45	10.22	11.17	10.82	11.28			10.87	0.34
6518vert.	$P_{max}-P_{20mm}$ kN/m	17.49	14.37	15.75	15.47	15.55	15.98	16.06	16.80	17.40			16.10	0.94
	e_{max} %	99.18	91.12	94.62	99.14	99.02	98.78	95.32	99.08	99.14			97.27	2.75
Trevira S.	P_{max} kN/m	23.18	24.95	24.06	27.42	26.72	23.34	23.85	23.20	24.09	26.26		24.71	1.48
300	P_{20mm} kN/m	10.37	11.46	10.82	12.09	11.45	9.83	10.74	10.18	10.80	11.46		10.92	0.66
6502vert.	$P_{max}-P_{20mm}$ kN/m	12.80	13.49	13.24	15.33	15.27	13.51	13.11	13.02	13.29	14.79		13.79	0.91
	e_{max} %	60.46	57.32	62.03	64.54	65.09	65.28	59.72	63.02	58.65	63.44		61.95	2.66
Terram	P_{max} kN/m	14.25	14.76	13.91	14.95	15.08	14.89	13.66	17.32	14.43	14.61		14.78	0.95
3000	P_{20mm} kN/m	13.20	13.76	13.41	13.73	13.61	13.71	13.02	15.45	13.44	13.40		13.67	0.64
3156vert.	$P_{max}-P_{20mm}$ kN/m	1.04	1.00	0.50	1.22	1.47	1.18	0.64	1.86	0.99	1.21		1.11	0.37
	e_{max} %	27.80	27.12	27.09	29.33	30.94	29.51	24.40	30.25	26.16	27.70		28.03	1.89

Tab. 4.4b Wide width tensile test (ISO 10 319). VTT-GEO class IV products. Machine direction

VTT-GEOTEXTILE SPECIFICATION, CLASS II		Tensile test results of different geotextile types at 200 mm width samples											
Geotextile type		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average	Stdv.
Bidim B-1	P_{max} LENGTH. kN/m	7.33	6.72	8.17	5.53	7.50	6.84	6.82	7.72	7.77	7.27		7.17	0.70
	P_{max} CROSS . kN/m	5.52	5.42	5.71	5.53	5.17	5.38	5.06	5.13	4.05			5.22	0.46
	A	1.33	1.24	1.43	1.00	1.45	1.27	1.35	1.51	1.92			1.39	0.23
Fibertex F-2B	P_{max} LENGTH. kN/m	8.18	7.85	7.41	8.45	7.95	7.26	7.90	6.81	5.24	8.11	6.92	7.46	0.86
	P_{max} CROSS . kN/m	6.80	9.56	8.72	7.43	7.88	6.74	6.42	9.20	7.47			7.80	1.06
	A	1.20	1.22	1.18	1.14	1.01	1.08	1.23	1.35	1.43			1.20	0.12
Polyfelt 22-ST	P_{max} LENGTH. kN/m	8.96	9.07	9.34	10.00	8.57	8.47	9.14	9.03	8.12	9.47	8.75	8.99	0.49
	P_{max} CROSS . kN/m	7.91	8.18	8.05	8.59	8.85	7.58	8.02	8.00	7.63			8.09	0.39
	A	1.13	1.11	1.16	1.16	1.03	1.12	1.14	1.13	1.06			1.12	0.04
Trevira S. 110	P_{max} LENGTH. kN/m	6.54	6.00	5.36	7.43	6.66	5.90	8.20	7.59	5.92	6.86		6.64	0.84
	P_{max} CROSS . kN/m	5.02	5.84	6.63	6.39	6.12	6.78	5.97	5.28				6.00	0.58
	A	1.30	1.03	1.24	1.16	1.09	1.15	1.37	1.44				1.22	0.13
Terram 1000	P_{max} LENGTH. kN/m	7.16	6.39	7.25	7.21	7.05	6.57	7.66	6.77	7.12	6.97		7.01	0.34
	P_{max} CROSS . kN/m	10.88	8.35	8.67	9.25	10.05	11.33	10.36	9.22	9.17			9.70	0.95
	A	1.52	1.31	1.20	1.28	1.42	1.72	1.35	1.36	1.29			1.38	0.15
Typar 136	P_{max} LENGTH. kN/m	6.73	6.98	6.70	6.00	7.54	6.31	7.31	7.01	6.36	5.57		6.65	0.57
	P_{max} CROSS . kN/m	7.65	6.47	8.02	7.26	6.74	7.08	6.89	7.81	7.02	6.70		7.16	0.49
	A	1.14	1.08	1.20	1.21	1.12	1.12	1.06	1.11	1.10	1.20		1.14	0.05

Tab. 4.5 Wide width t ensile test (ISO 10 319). Maximum tensile strength and uniformity values. VTT-GEO class II products.

VTT-GEOTEXTILE SPECIFICATION, CLASS III		Tensile test results of different geotextile types at 200 mm width samples												
Geotextile type		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average	Stdv.
Bidim B-3	P_{max} LENGTH. kN/m	8.85	9.00	11.11	10.16	9.61	9.52	10.95	10.81	10.77	10.29		10.10	0.78
	P_{max} CROSS . kN/m	8.62	7.42	7.58	9.39	10.03	9.98	8.58	8.56	10.02	9.80		9.00	0.94
	A	1.03	1.21	1.47	1.08	1.04	1.05	1.28	1.26	1.08	1.05		1.15	0.14
Fibertex F-32M	P_{max} LENGTH. kN/m	7.09	7.61	7.66	7.28	8.60	8.66	7.82	7.50	8.51	7.87		7.86	0.53
	P_{max} CROSS . kN/m	10.29	9.29	11.29	10.36	11.80	10.18	11.54	11.66	10.98	11.61		10.90	0.79
	A	1.45	1.22	1.47	1.42	1.37	1.18	1.48	1.56	1.29	1.48		1.39	0.12
Polyfelt TS-500 (TS-21)	P_{max} LENGTH. kN/m	12.52	13.72	12.90	12.35	14.22	10.53	11.88	14.16				12.78	1.17
	P_{max} CROSS . kN/m	13.50	13.53	12.42	11.92	13.06	15.08	15.54	13.51	14.43	12.96		13.59	1.08
	A	1.08	1.01	1.04	1.04	1.09	1.43	1.31	1.05				1.13	0.14
Trevira S. 150	P_{max} LENGTH. kN/m	10.19	8.17	8.54	7.60	8.84	8.55	8.73	9.12	7.79	8.13		8.56	0.70
	P_{max} CROSS . kN/m	9.23	9.99	8.87	10.28	11.41	10.49	10.96	10.30	11.84	9.76		10.31	0.88
	A	1.10	1.22	1.04	1.35	1.29	1.23	1.26	1.13	1.52	1.20		1.23	0.13
Terram 1500	P_{max} LENGTH. kN/m	13.39	8.89	12.10	8.85	10.40	10.18	11.37	12.60	11.32	11.71		11.08	1.42
	P_{max} CROSS . kN/m	14.11	12.67	12.97	15.19	14.75	16.26	13.09	13.43	9.66	11.87		13.40	1.76
	A	1.05	1.43	1.07	1.72	1.42	1.60	1.15	1.07	1.17	1.01		1.27	0.24
Typar 230	P_{max} LENGTH. kN/m	15.11	14.25	14.60	14.82	13.46	14.58	14.27	14.62	13.98	14.05		14.37	0.45
	P_{max} CROSS . kN/m	13.14	16.02	16.25	16.22	14.49	15.86	15.25	13.14	15.21	16.28		15.18	1.16
	A	1.15	1.12	1.11	1.09	1.08	1.09	1.07	1.11	1.09	1.16		1.11	0.03

Tab. 4.6 Wide width tensile test (ISO 10 319). Maximum tensile strength and uniformity values. VTT-GEO class III products.

VTT-GEOTEXTILE SPECIFICATION, CLASS IV		Tensile test results of different geotextile types at 200 mm width samples												
Geotextile type		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average	Stdv.
Bidim B-7	P_{max} LENGTH. kN/m	23.04	23.54	21.73	24.55	23.78	22.61	25.14	27.09	20.45	24.12		23.60	1.75
	P_{max} CROSS . kN/m	22.26	22.58	20.85	22.81	23.94	22.11	22.50	22.55	24.82	23.94		22.83	1.07
	A	1.04	1.04	1.04	1.08	1.01	1.02	1.12	1.20	1.21	1.01		1.08	0.07
Fibertex F-4M	P_{max} LENGTH. kN/m	13.75	11.74	12.97	15.88	16.65	12.55	13.29	13.47	15.08	15.63		14.10	1.53
	P_{max} CROSS . kN/m	20.15	22.71	20.16	21.60	22.49	22.96	22.23	19.96	19.26	20.53		21.20	1.27
	A	1.47	1.93	1.55	1.36	1.35	1.83	1.67	1.48	1.28	1.31		1.52	0.21
Polyfelt TS-750	P_{max} LENGTH. kN/m	28.47	25.45	26.94	26.16	26.00	26.19	27.23	27.62	28.69			26.97	1.07
	P_{max} CROSS . kN/m	18.24	19.09	18.10	17.74	17.82	19.61	18.44	16.38	17.73	18.29		18.14	0.82
	A	1.56	1.33	1.49	1.47	1.46	1.34	1.48	1.69	1.62			1.49	0.11
Trevira S. 300	P_{max} LENGTH. kN/m	23.18	24.95	24.06	27.42	26.72	23.34	23.85	23.20	24.09	26.26		24.71	1.48
	P_{max} CROSS . kN/m	22.16	21.57	20.36	21.82	22.19	21.60	21.26	22.40	20.69	23.03		21.71	0.76
	A	1.05	1.16	1.18	1.26	1.20	1.08	1.12	1.04	1.16	1.14		1.14	0.07
Terram 3000	P_{max} LENGTH. kN/m	14.25	14.76	13.91	14.95	15.08	14.89	13.66	17.32	14.43	14.61		14.78	0.95
	P_{max} CROSS . kN/m	17.93	19.74	17.71	19.47	20.59	19.30	18.98	18.70	16.45	19.61		18.85	1.14
	A	1.26	1.34	1.27	1.30	1.37	1.30	1.39	1.08	1.14	1.34		1.28	0.09

Tab. 4.7 Wide width tensile test (ISO 10 319). Maximum tensile strength and uniformity values. VTT-GEO class IV products.

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